REDES DE QUINTA GENERACIÓN
Curso básico
Módulo 3

CePETel

CePETel
Sindicato de los Profesionales
de las Telecomunicaciones

SECRETARÍA TÉCNICA

IPEI

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TEMARIO

MODULO 1
La evolución histórica de las redes móviles. 2G/3G/4G.
Rol de 3GPP en la standarización.
Redes 4: LTE y EPC.
Conceptos heredados de LTE. Conceptos específicos de 5G.

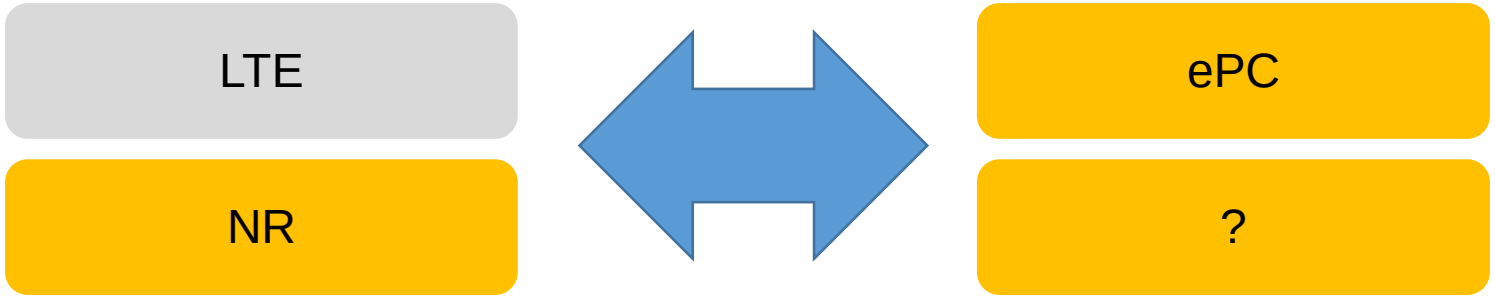
MODULO 2
Motivadores para el despliegue de una red 5G. Por dónde empezar.
Concepto de Dual Connectivity.
Los terminales: Bandas, road map, chipsets. Impacto en la estrategia de despliegue.
La red de Acceso: Bandas, aspectos de propagación, ancho de banda.
El Núcleo: arquitectura a alto nivel.

MODULO 3
Arquitectura NSA. Visión de alto nivel.
Opciones de interconexión.
Planificación de red 5G inicial. Casos de uso.
DSS.Conceptos, posibles aplicaciones.

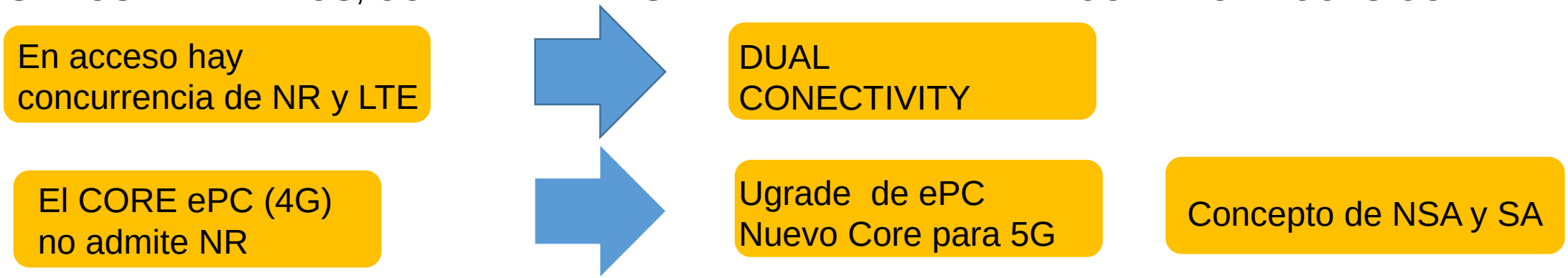
MODULO 4
Arquitectura SA. Visión de alto nivel.
Principales Desafíos de SA..
Impacto de 5G en IMS y servicios de tiempo real.

LTE & EPC

CONSIDERACIONES DE ALTO NIVEL SOBRE LA CONEXIÓN AL CORE



DESAFÍOS INMEDIATOS, CONLLEVAN MAS FLEXIBILIDAD DE INTERCONEXIÓN ACCES-CORE



A diferencia de 4G, en las redes 5G, el Acceso y el Core pueden evolucionar independientemente. Las estaciones 4G y 5G se conectan a cada Core respectivamente, sin embargo, con las adecuaciones necesarias, es posible utilizar “Dual Conectivity” para mejorar los tiempos de despliegue y utilizar infraestructura pre existente, permitiendo de ese modo una evolución mas suave.
En 5G aparecen además los conceptos de NSA y SA asociados a lo anterior

CONSIDERACIONES DE ALTO NIVEL SOBRE LA CONEXIÓN AL CORE

NSA, se apoya sobre el ePC pre-existente para lo cual, para poder interconectarse con NR se requieren adecuaciones (ePC+)

Non-Standalone (NSA) NR: During this phase, NR is expected to utilize the existing LTE Radio Access Network (RAN) and Core Network (CN) functionalities accordingly modified to handle the addition of a new 5G carrier targeting late 2018 (early 2019) NR NSA deployments.

SA , podría considerarse como el modelo objetivo si no existiera LTE, sin embargo la convivencia con LTE implica retos

Standalone (SA) NR: In this phase, a full set of CP and Upnfunctionalities will be specified to fully exploit the 5G capabilities driven by the ITU targets. Furthermore,3GPP will also specify a new CN architecture for 5G enabling new features such as network slicing.With the completion of the second phase, NR will be able to operate with a full set of 5G capabilities without the need of the LTE co-existence.

La interconexión entre NR y LTE con el ePC plantea alternativas (options).
No olvidar que existe un plano de usuario y otro de control

CONSIDERACIONES DE ALTO NIVEL SOBRE LA CONEXIÓN AL CORE

NR NSA: interim set of approved specifications end of December 2017 (ASN.1 due in March 2018). This first set defines 5G New Radio (NR) in Non- Standalone operation (NSA) enabling 5G NR deployments using existing 4G systems (LTE EUTRAN and EPC) as leverage.

NR SA: The specifications of 5G NR in Standalone operation are due for completion in June 2018 (ASN.1 due in September 2018), complemented by the complete set of specifications of the new 5G Core Network – hence the full 5G System.

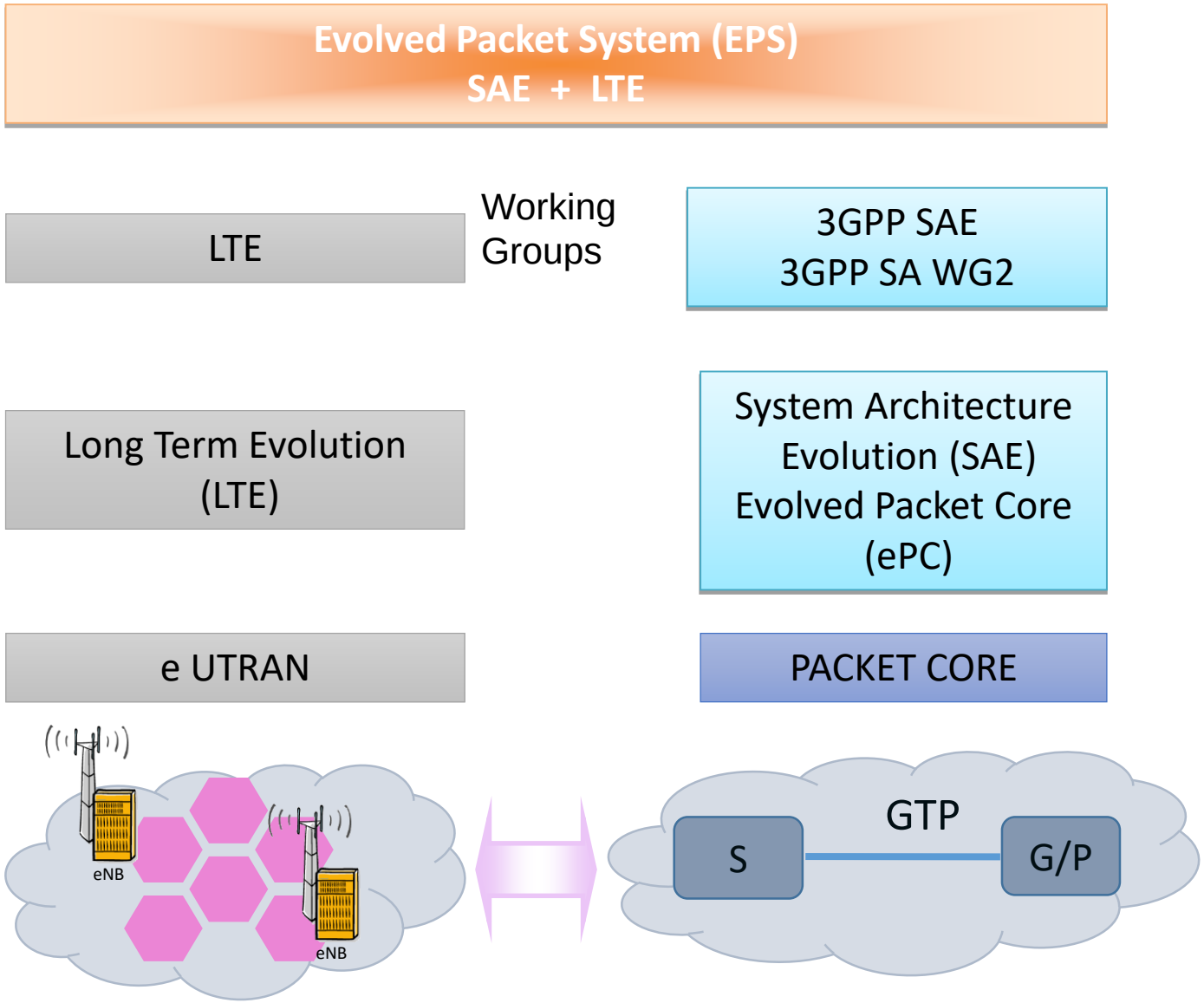
RESUMEN ARQUITECTURA LTE

Conceptos que siguen siendo válidos en 5G

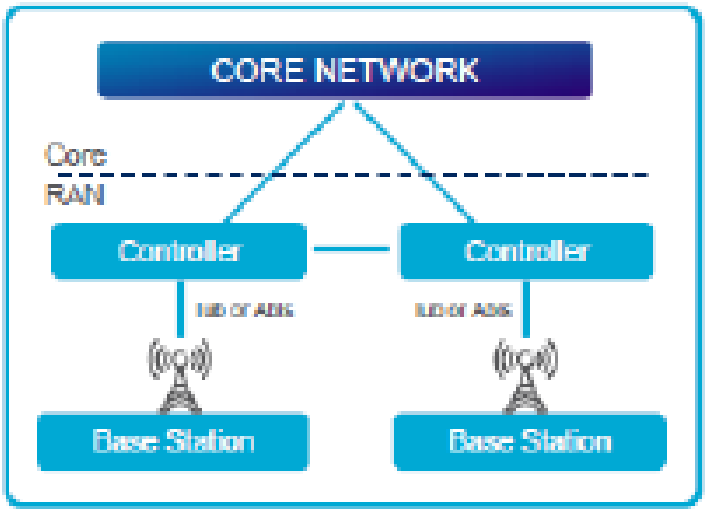
ARQUITECTURA DE RED

EPC- Terminología

LTE has been designed to support only Packet-Switched (PS) services, in contrast to the Circuit-Switched (CS) model of previous cellular systems.
It aims to provide seamless Internet Protocol (IP) connectivity between User Equipment (UE) and the Packet Data Network (PDN), without any disruption to the end users applications during mobility.

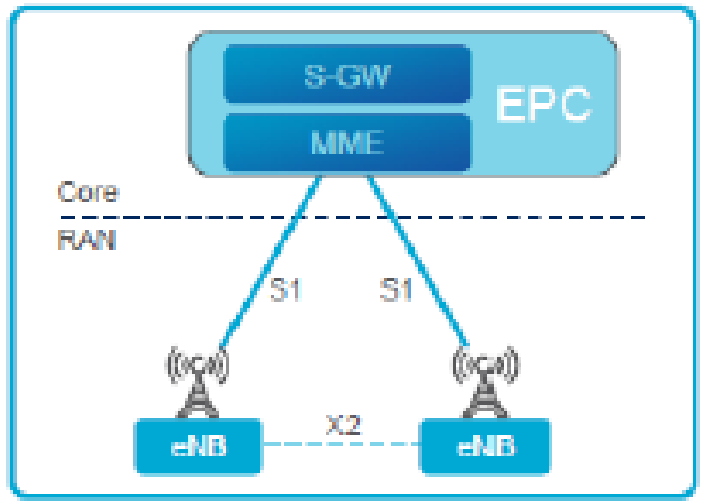


EPC- Visión de Alto nivel



2G/3G

Dos Cores: uno exclusivo para la voz y SMS, y otro para Datos



LTE

Único Core de Paquetes, tanto para datos , como también voz video.
Separación del plano de control y el plano de usuario

EPC- Visión de Alto nivel

IMS & LTE: Arquitectura basada en IP / Bearers

EPS uses the concept of *EPS bearers* to route IP traffic from a gateway in the PDN to the UE. A bearer is an IP packet flow with a defined Quality of Service (QoS). The E-UTRAN and EPC together set up and release bearers as required by applications. EPS natively supports voice services over the IP Multimedia Subsystem (IMS) using Voice over IP VoIP), but LTE also supports interworking with legacy systems for traditional CS voice support.

PDN connection default

IP1

PDN connection 2:
QoS, priority, HDCodec

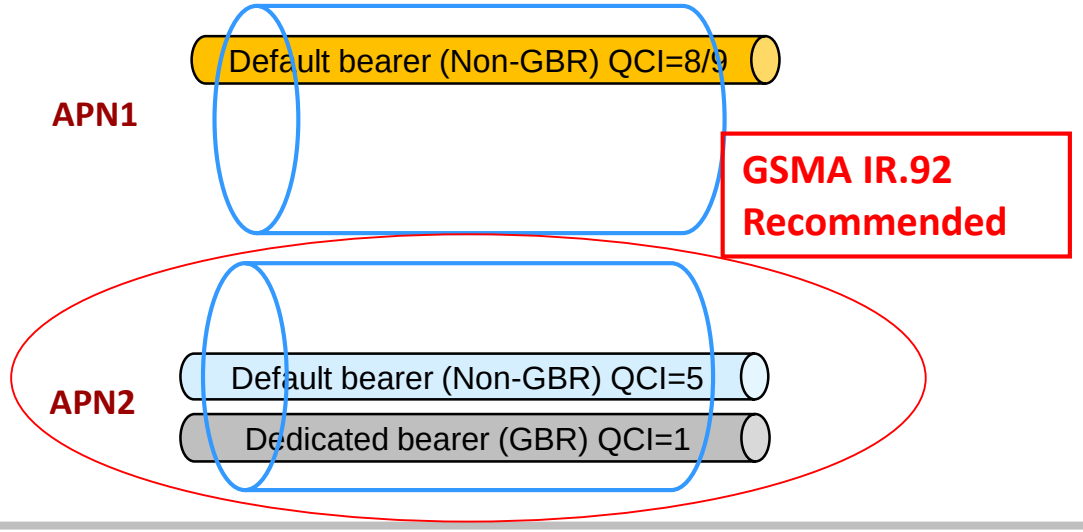
IP2

Internet

IMS

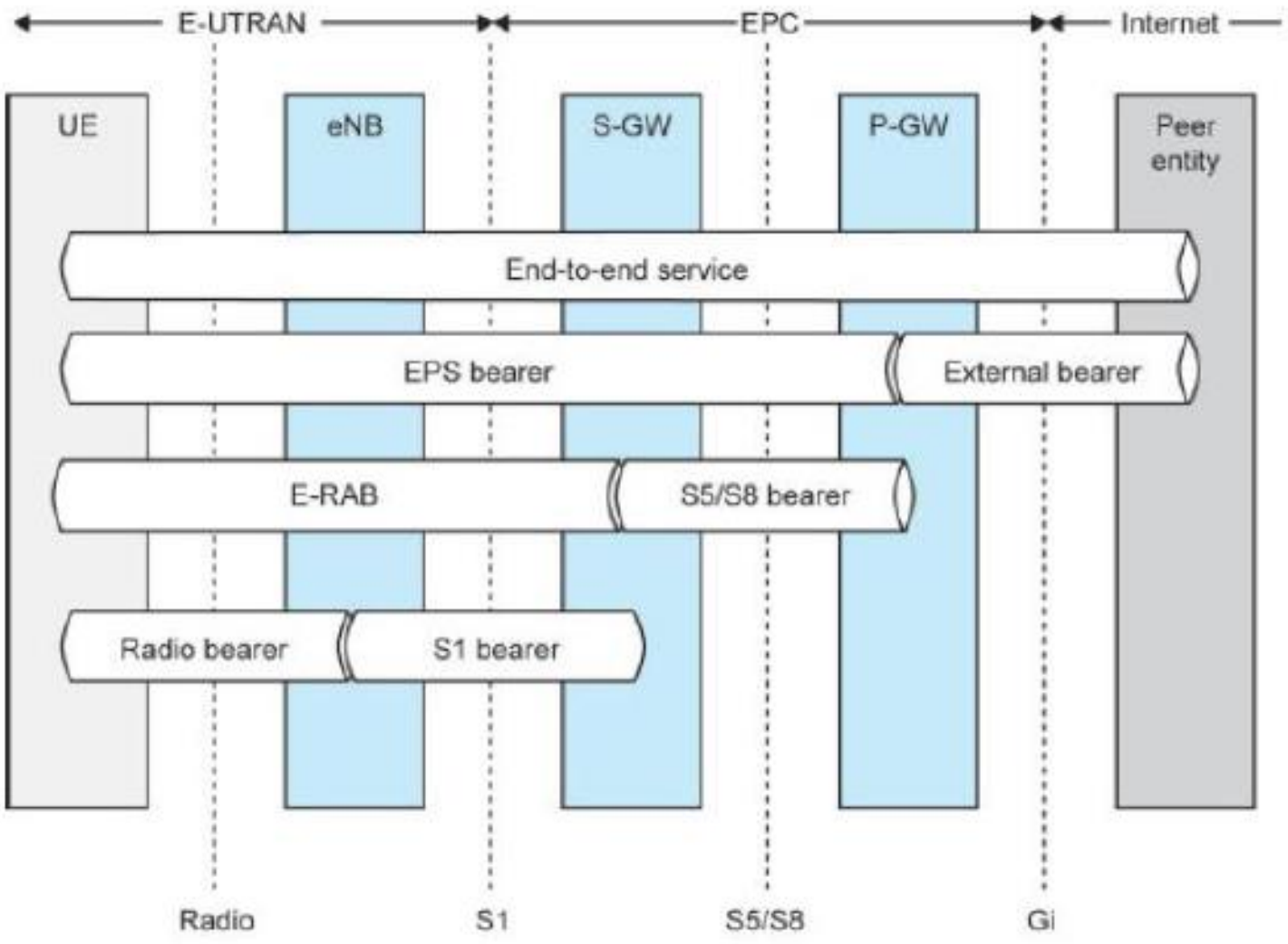
UE sends APN info in order to select PDN, or network selects the default APN by consulting HSS (subscription)

Different APNs are used for data and IMS services.



- Default bearer QCI=8/9 in APN1
- Default bearer QCI=5 in APN2: IMS signaling
- Dedicated bearer QCI=1 in APN2: IMS voice

ARQUITECTURA DE RED
IMS & LTE: E2E QoS Concept



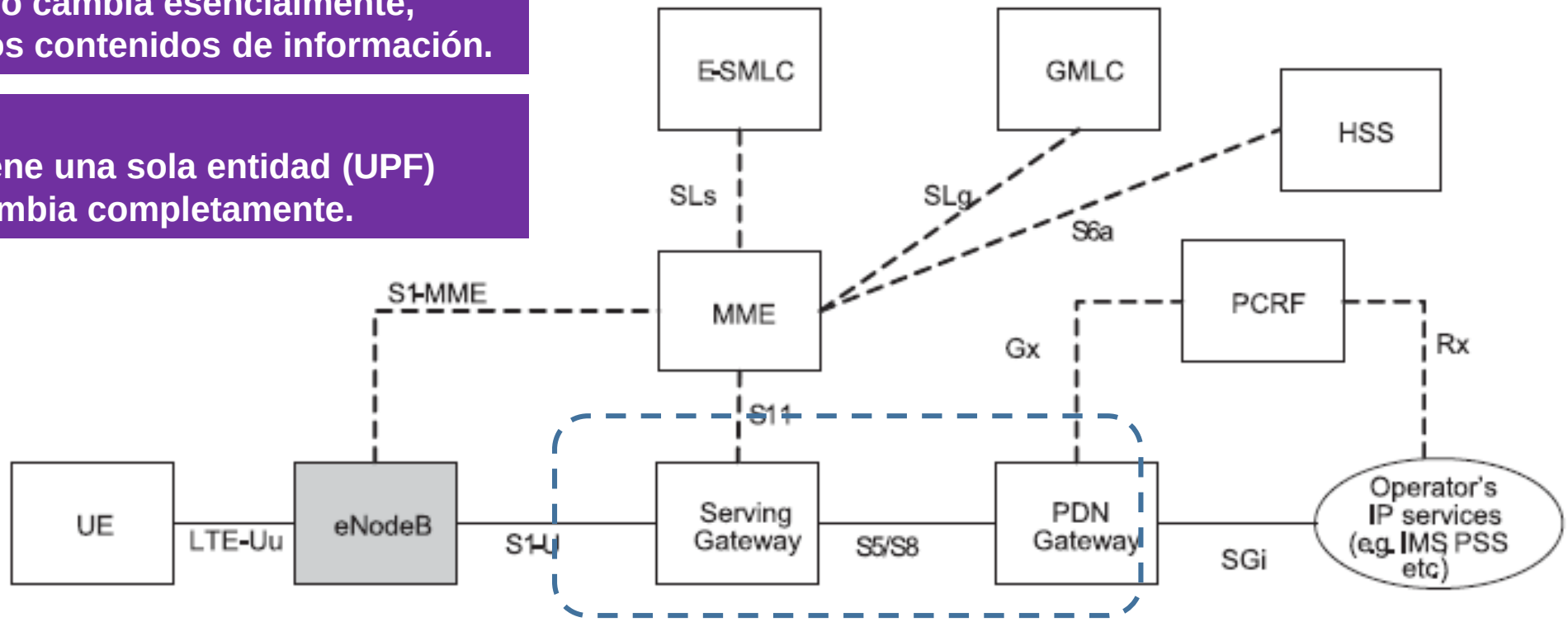
Al no disponer de un canal o circuito dedicado como en el caso de tecnologías anteriores (TDM), se requiere aplicar Calidad de Servicio extremo a extremo, involucrando todos los dominios

ARQUITECTURA DE RED

Multiple bearers can be established for a user in order to provide different QoS streams or connectivity to different PDNs. For example, a user might be engaged in a voice (VoIP) call while at the same time performing web browsing or File Transfer Protocol (FTP) download.

En 5G NSA:
La estructura de ePC no cambia esencialmente, solo hay cambios en los contenidos de información.

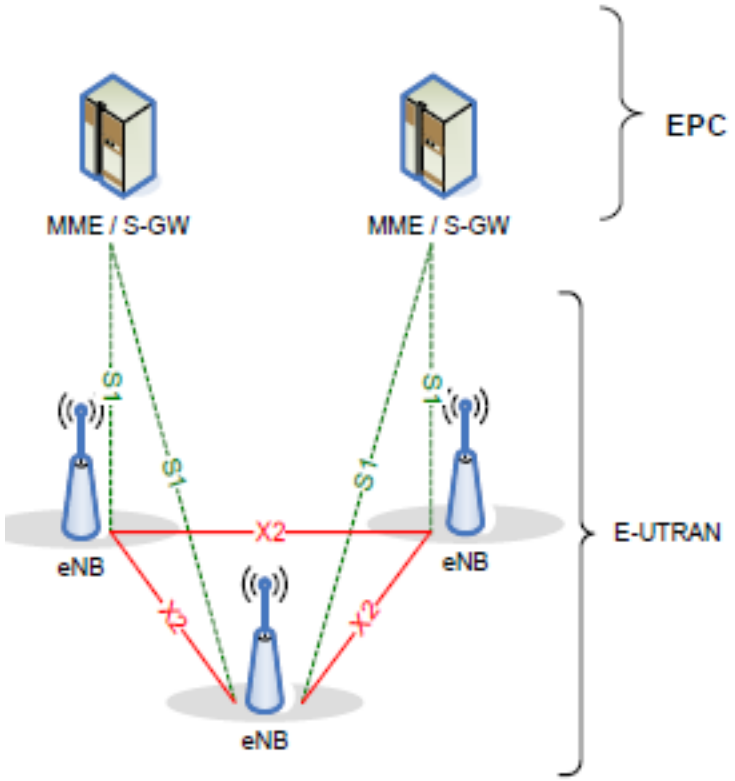
En 5G SA:
El plano de Usuario tiene una sola entidad (UPF)
El plano de Control cambia completamente.

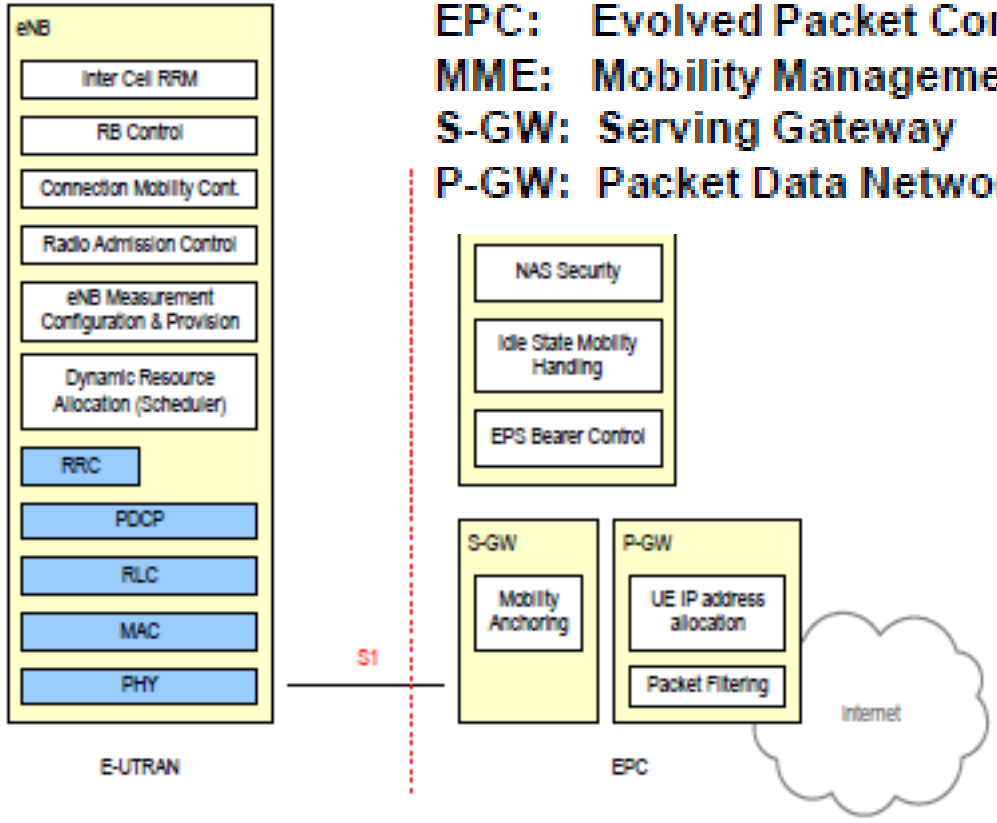


Terminal | Red de acceso | Núcleo o Core de Paquetes | Politicas | Aplicaciones

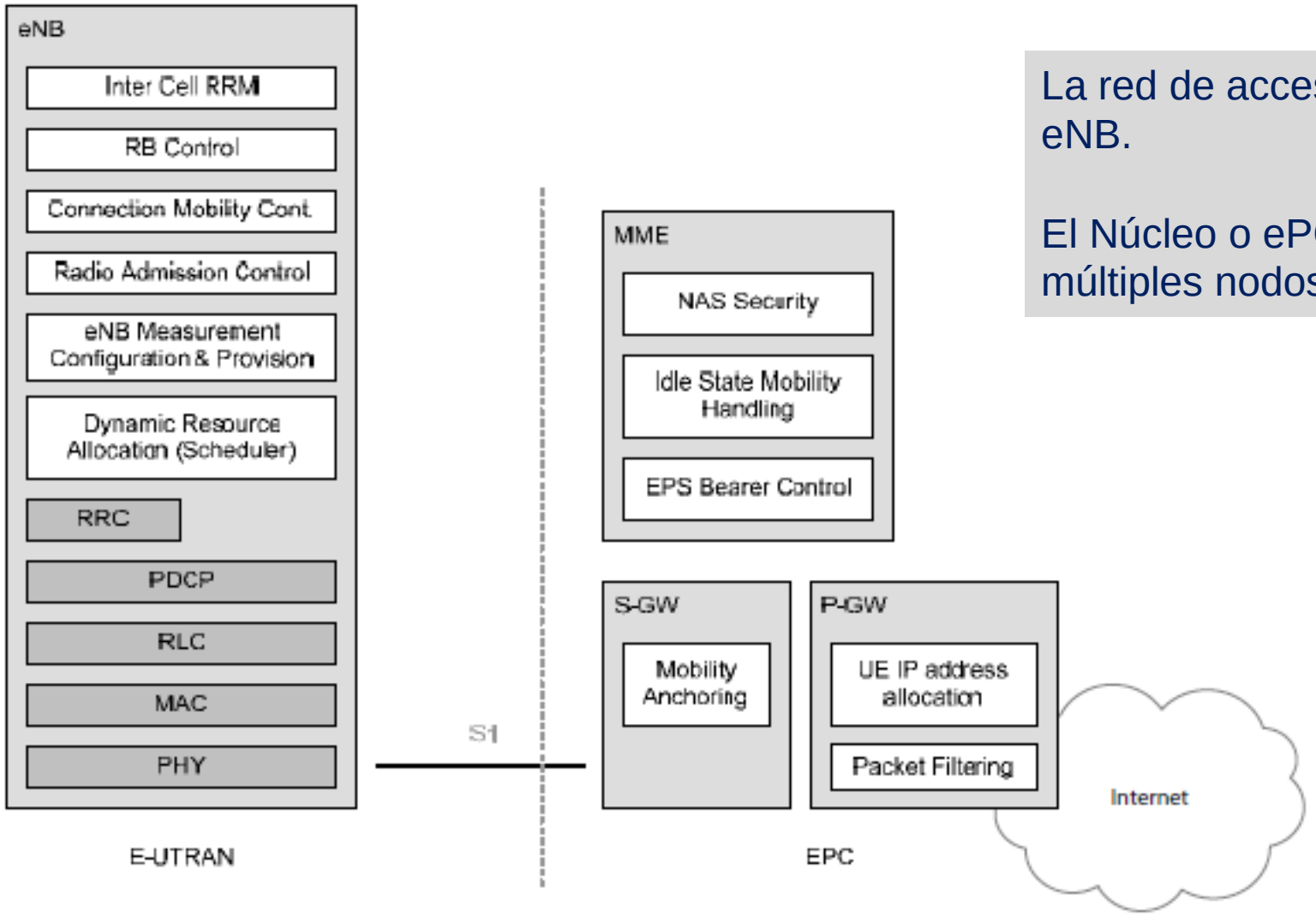
ARQUITECTURA DE RED

RRC: Radio Resource Control
PDCP: Packet Data Convergence Protocol
RLC: Radio Link Control
MAC: Medium Access Control
PHY: Physical layer
EPC: Evolved Packet Core
MME: Mobility Management Entity
S-GW: Serving Gateway
P-GW: Packet Data Network Gateway





Arquitectura: Acceso & Núcleo

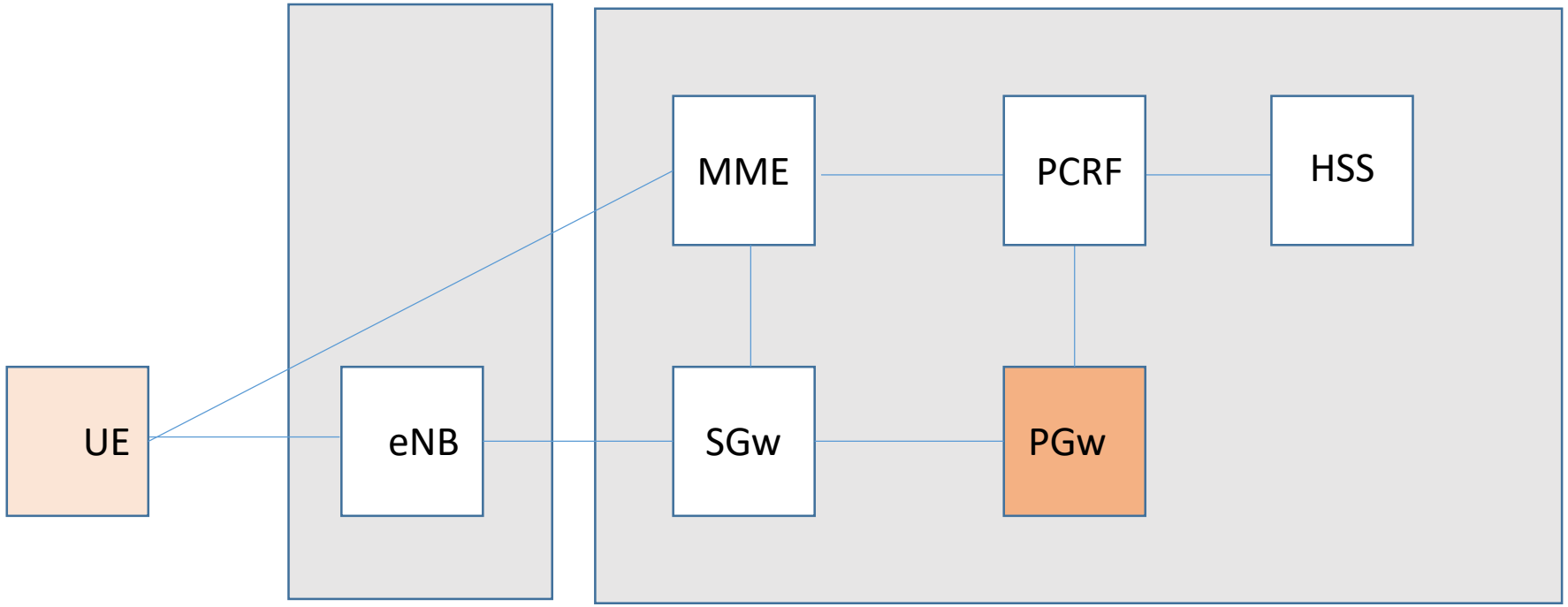


La red de acceso consta de un solo nodo: eNB.

El Núcleo o ePC, es una red compuesta de múltiples nodos.

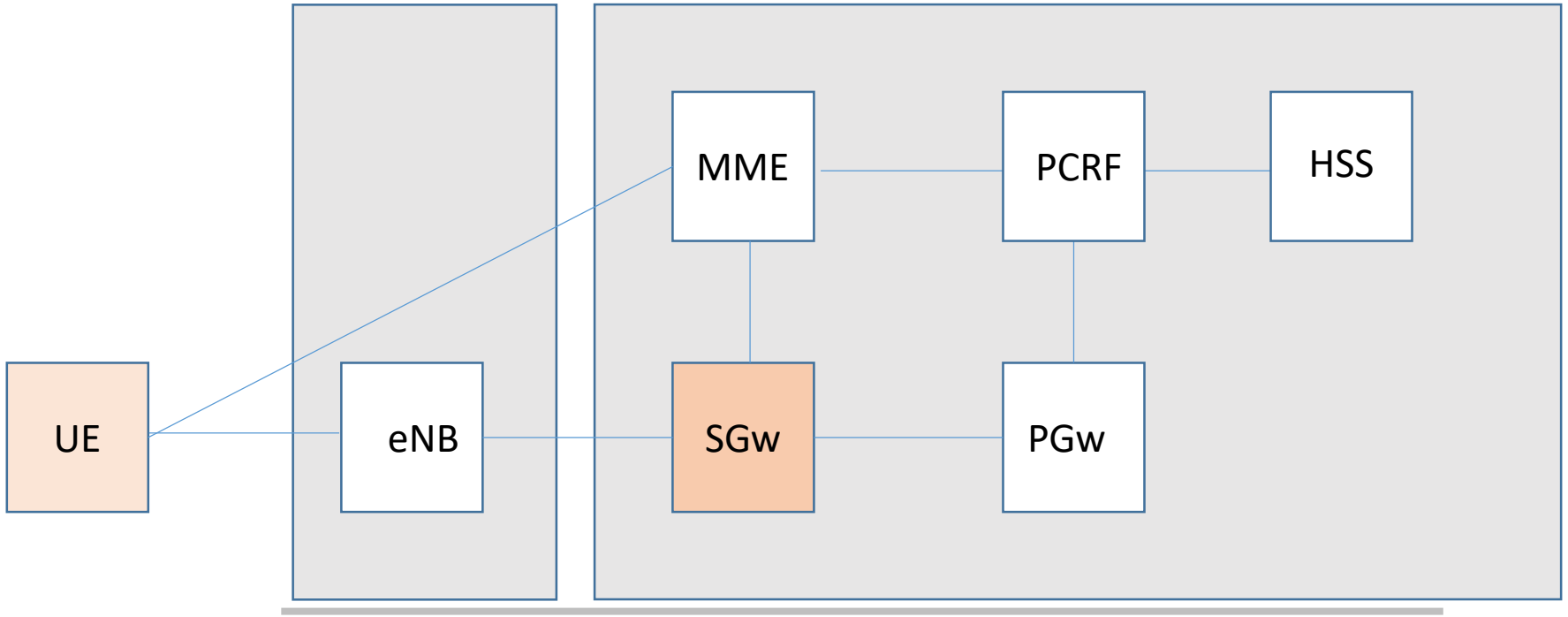
Arquitectura: Descripción de elementos de C.N

P-GW. The P-GW is responsible for IP address allocation for the UE, as well as QoS enforcement and flow-based charging according to rules from the PCRF. The P-GW is responsible for the filtering of downlink user IP packets into the different QoS-based bearers. This is performed based on Traffic Flow Templates (TFTs).
The P-GW performs QoS enforcement for Guaranteed Bit Rate (GBR) bearers. It also serves as the mobility anchor for inter-working with non-3GPP technologies such as CDMA2000 and WiMAX



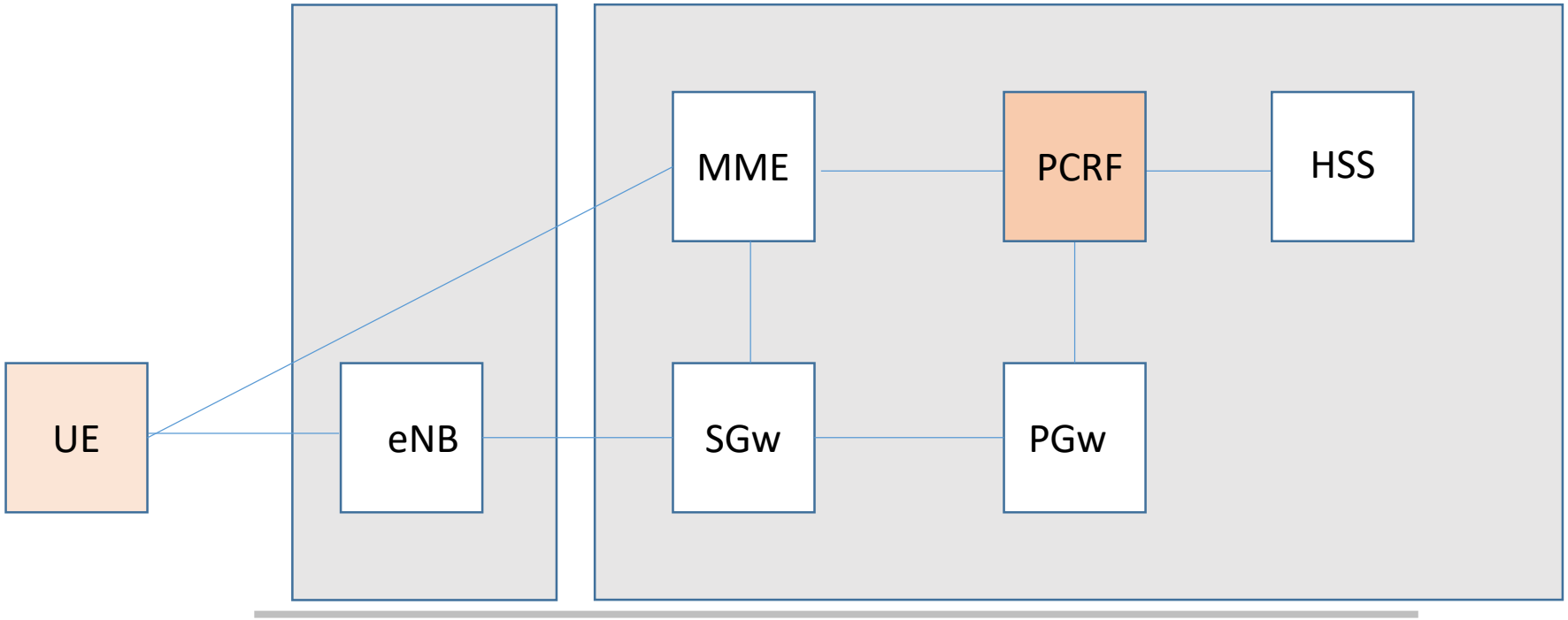
Arquitectura: Descripción de elementos de C.N

S-GW. All user IP packets are transferred through the S-GW, which serves as the local mobility anchor for the data bearers when the UE moves between eNodeBs. It also retains the information about the bearers when the UE is in idle state (known as EPS Connection Management IDLE (ECM-IDLE)) and temporarily buffers downlink data while the MME initiates paging of the UE to re-establish the bearers. In addition, the S-GW performs some administrative functions in the visited network, such as collecting information for charging (e.g. the volume of data sent to or received from the user) and legal interception. It also serves as the mobility anchor for inter-working with other 3GPP technologies such as GPRS[3] and UMTS.



Arquitectura: Descripción de elementos de C.N

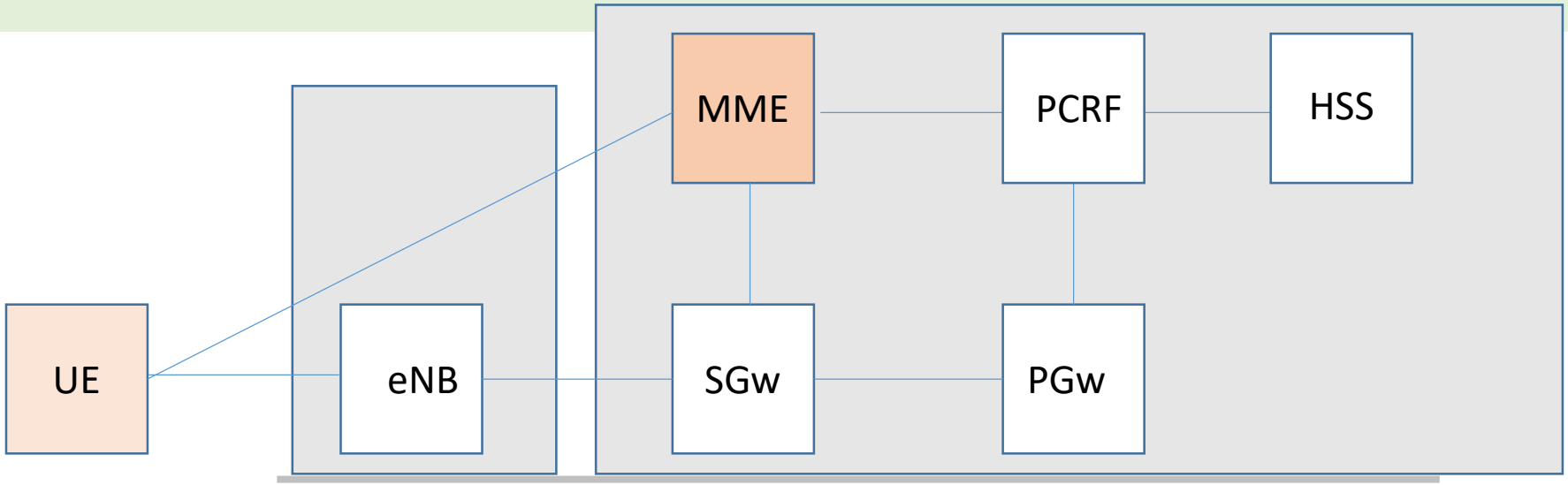
PCRF. The PCRF is responsible for policy control decision-making, as well as for controlling the flow-based charging functionalities in the Policy Control Enforcement Function (PCEF) which resides in the P-GW. The PCRF provides the QoS authorization (QoS class identifier and bit rates) that decides how a certain data flow will be treated in the PCEF and ensures that this is in accordance with the user's subscription profile.



Arquitectura: Descripción de elementos de C.N

MME. The MME is the control node which processes the signalling between the UE and the CN. The protocols running between the UE and the CN are known as the *Non-Access Stratum* (NAS) protocols.
The main functions supported by the MME are classified as:

Functions related to bearer management. This includes the establishment, maintenance and release of the bearers, and is handled by the session management layer in the NAS protocol.
Functions related to connection management. This includes the establishment of the connection and security between the network and UE, and is handled by the connection or mobility management layer in the NAS protocol layer.
Functions related to inter-working with other networks. This includes handing over of voice calls to legacy networks.

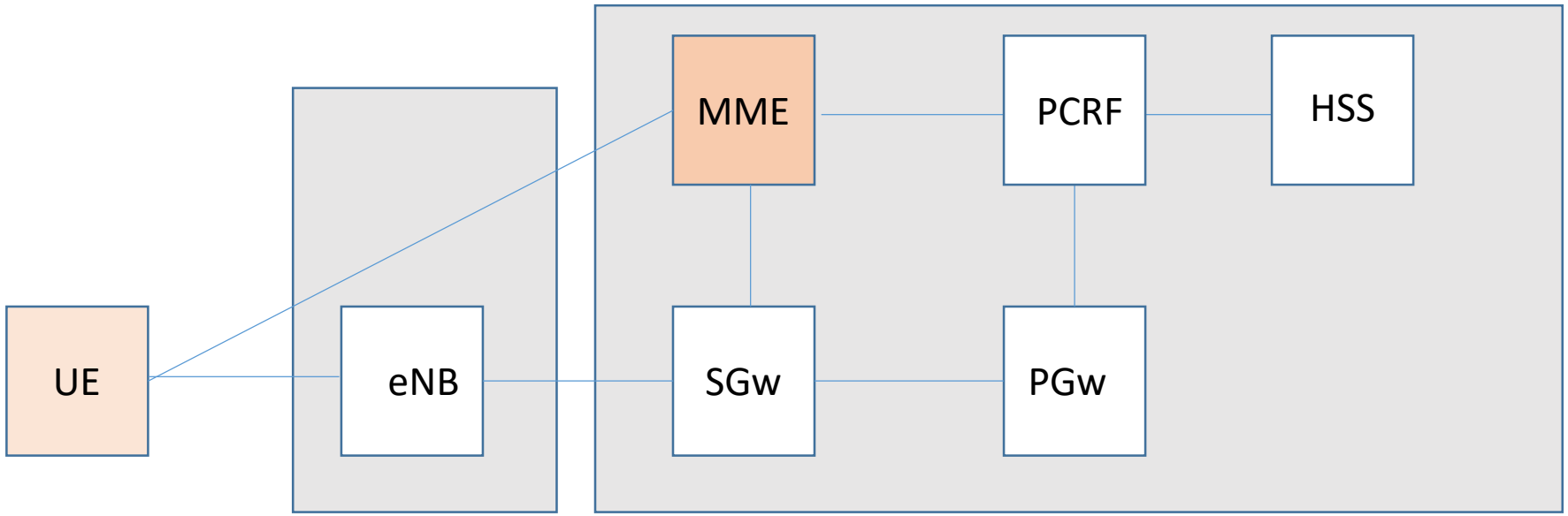


Arquitectura: Descripción de elementos de C.N

Non-Access Stratum (NAS) Procedures:
The NAS procedures, especially the connection management procedures, are fundamentally similar to UMTS. The main change from UMTS is that EPS allows concatenation of some procedures so as to enable faster establishment of the connection and the bearers.

The MME creates a *UE context* when a UE is turned on and attaches to the network.
It assigns to the UE a unique short temporary identity termed the SAE-Temporary Mobile Subscriber Identity (S-TMSI) which identifies the UE context in the MME.

To allow the network to contact an ECM-IDLE UE, the UE updates the network as to its new location whenever it moves out of its current Tracking Area (TA); this procedure is called a 'Tracking Area Update'.



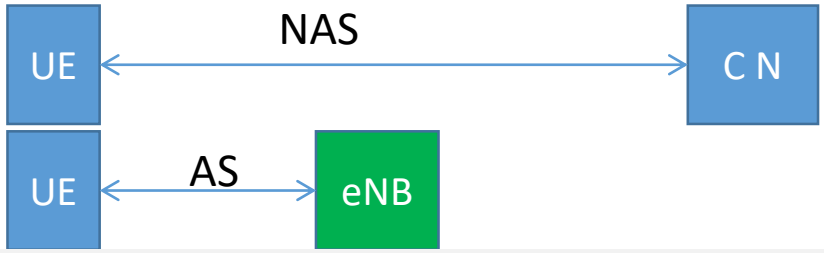
Arquitectura: Seguridad y procedimientos de by pass

Security functions are the responsibility of the MME for both signalling and user data.
When a UE attaches with the network, a mutual authentication of the UE and the network is performed between the UE and the MME/HSS. This authentication function also establishes the security keys which are used for encryption of the bearers.

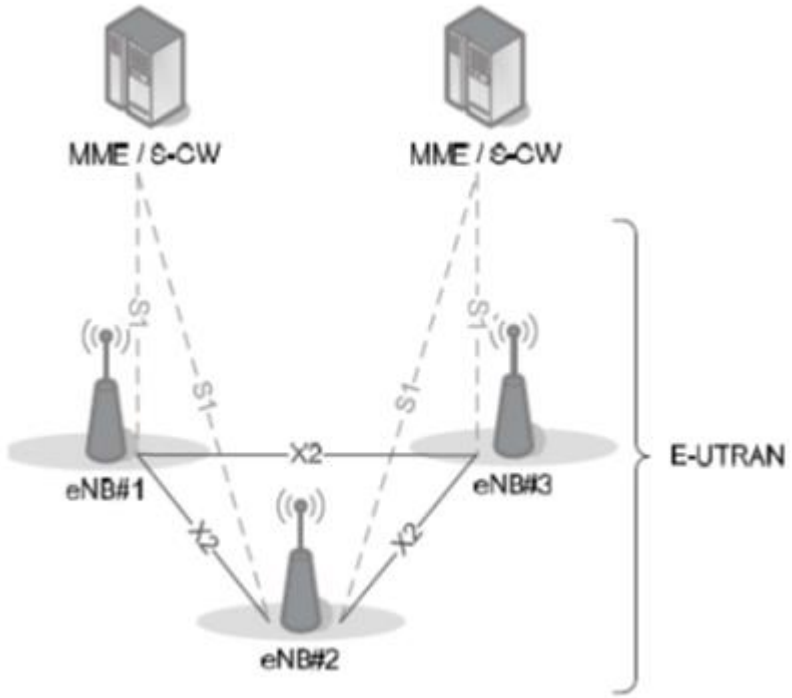
The NAS also handles IMS Emergency calls, whereby UEs without regular access to the network (i.e. terminals without a Universal Subscriber Identity Module (USIM) or UEs in limited service mode) are allowed access to the network using an 'Emergency Attach' procedure; this bypasses the security requirements but only allows access to an emergency P-GW.

MME se encarga de la autenticación mutua, consultando al HSS
NAS permite establecer llamadas de emergencias sin USIM

Arquitectura: Descripción de elementos de A.N



S1-MME, S1-U (AS).

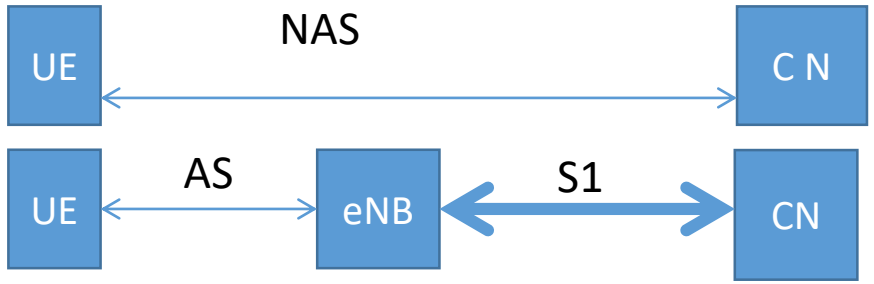


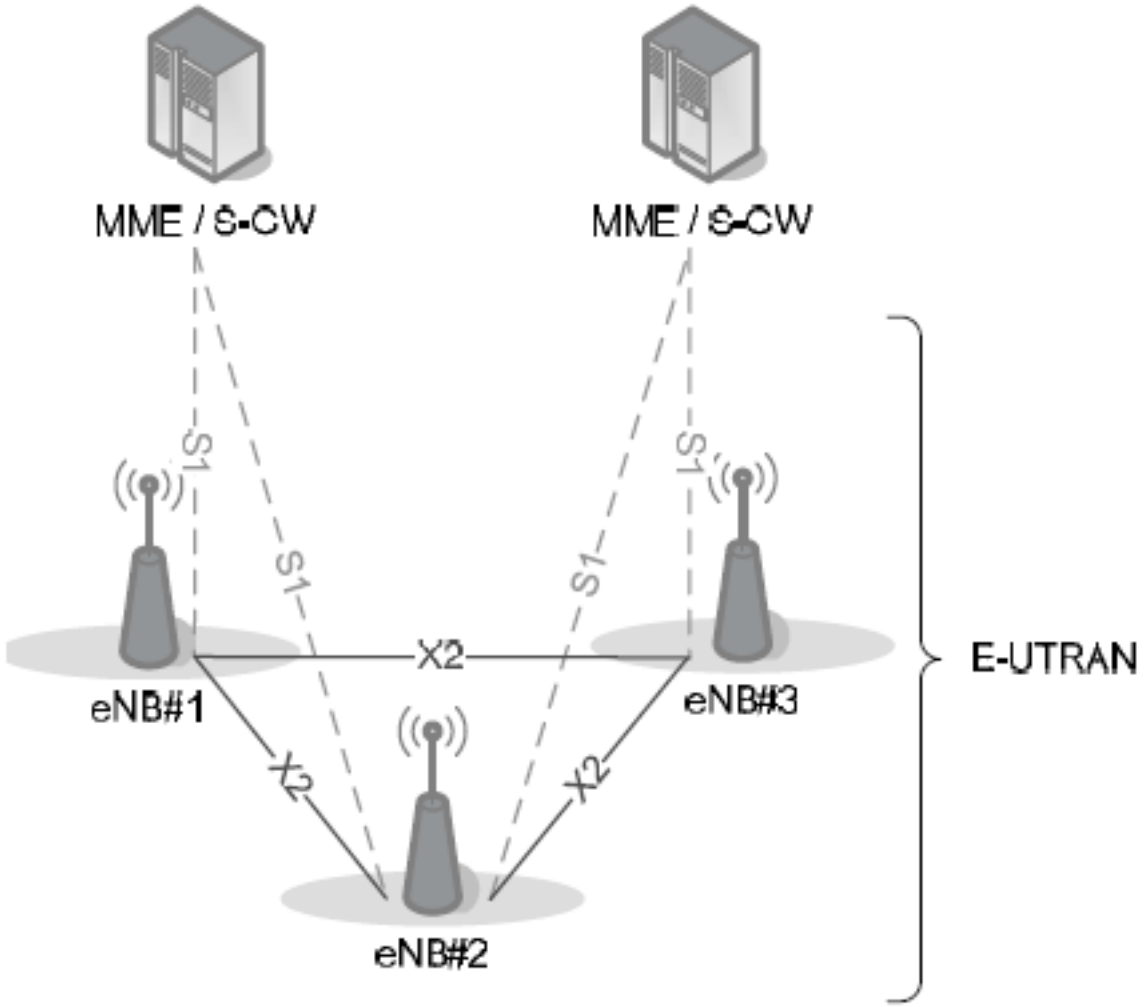
- **Radio Resource Management.** This covers all functions related to the radio bearers, such as radio bearer control, radio admission control, radio mobility control, scheduling and dynamic allocation of resources to UEs in both uplink and downlink.
- **Header Compression.** This helps to ensure efficient use of the radio interface by compressing the IP packet headers which could otherwise represent a significant overhead, especially for small packets such as VoIP.
- **Security.** All data sent over the radio interface is encrypted.
- **Positioning.** The E-UTRAN provides the necessary measurements and other data to the E-SMLC and assists the E-SMLC in finding the UE position.
- **Connectivity to the EPC.** This consists of the signalling towards the MME and the bearer path towards the S-GW.

One consequence of the lack of a centralized controller node is that, as the UE moves, the network must transfer all information related to a UE, i.e. the UE context, together with any buffered data, from one eNodeB to another. Some mechanisms are therefore needed to avoid data loss during handover. The operation of the X2 interface for this purpose..

Arquitectura: Descripción de elementos de A.N

S1-MME, S1-U (AS).





S1-flex. This is a concept whereby multiple CN nodes (MME/S-GWs) can serve a common geographical área.

The set of MME/S-GW nodes serving a common area is called an *MME/S-GW pool* ,

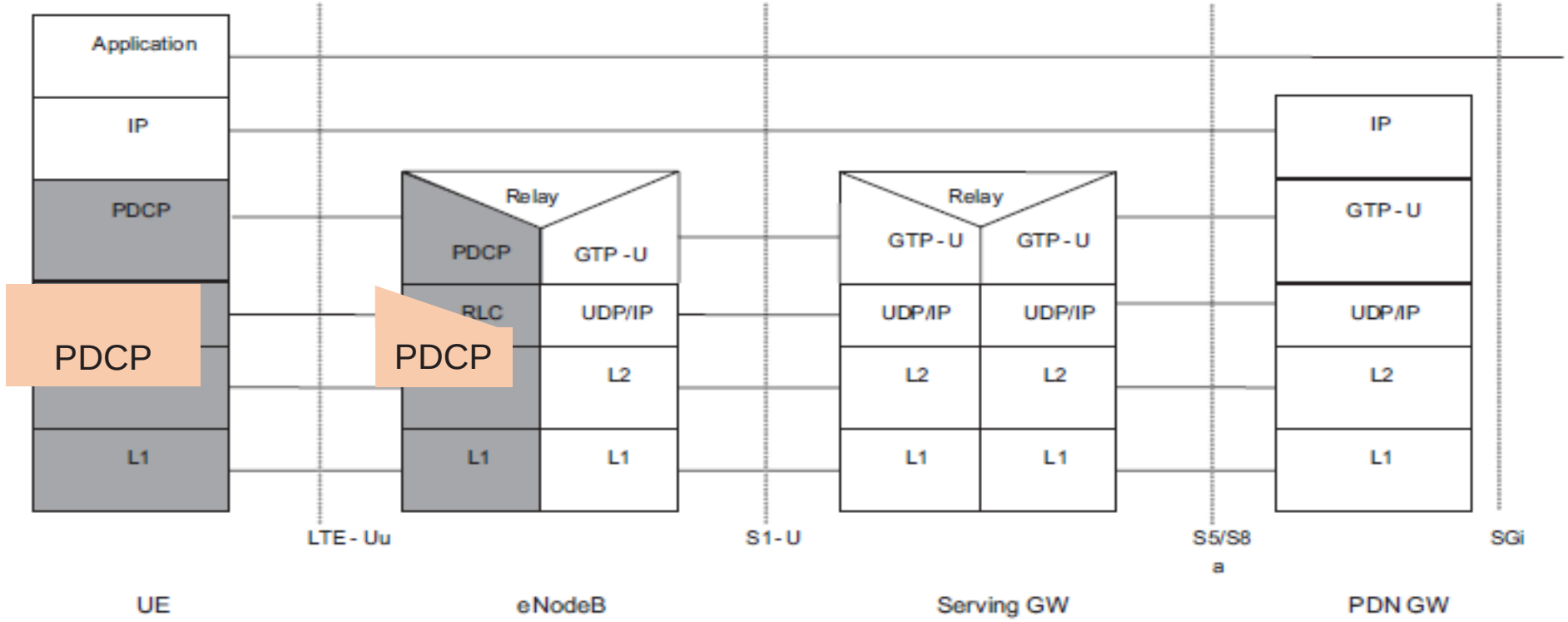
operation of the X2 interface for this purpose..

LTE: User Plane

An IP packet for a UE is encapsulated in an EPC-specific protocol and tunnelled between the P-GW and the eNodeB for transmission to the UE. Different tunnelling protocols are used across different interfaces. A 3GPP-specific tunnelling protocol called the GPRS Tunnelling Protocol (GTP) is used over the core network interfaces, S1 and S5/S8.

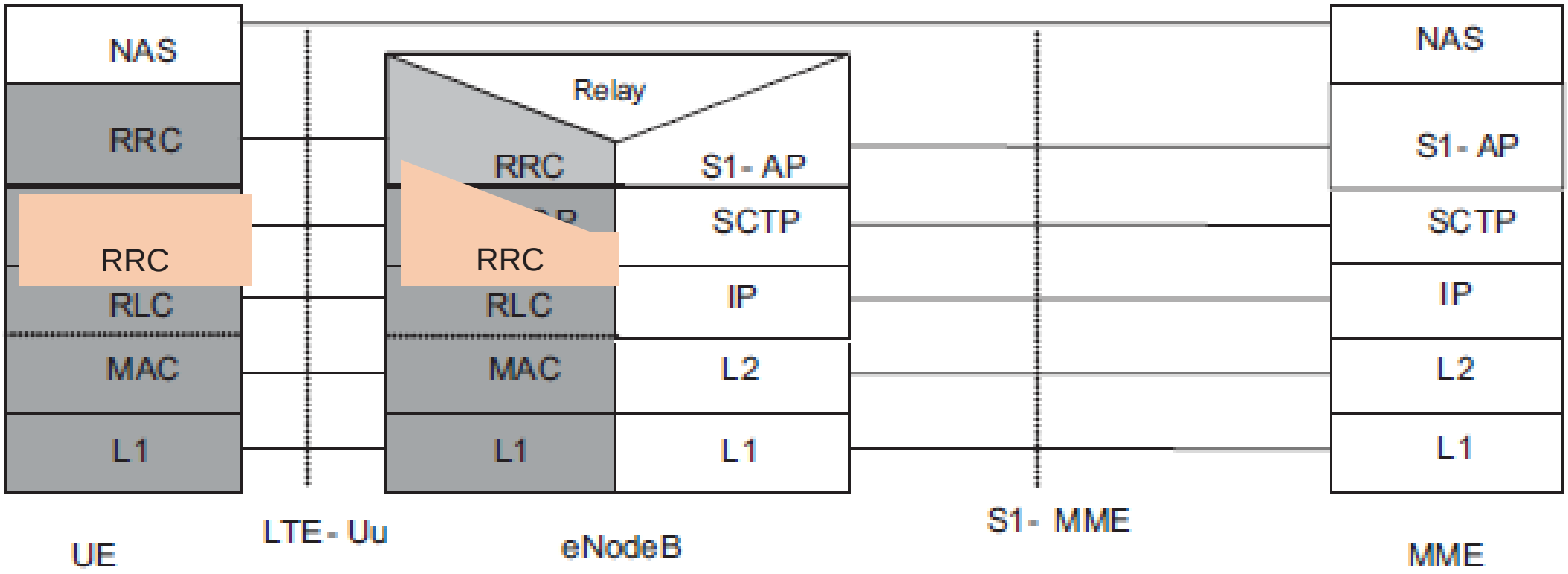
The E-UTRAN user plane protocol stack, shown greyed in Figure, consists of the Packet Data Convergence Protocol (PDCP), Radio Link Control (RLC) and Medium Access Control (MAC) sublayers which are terminated in the eNodeB on the network side.

Que significa Relay?



LTE: Control Plane

The Radio Resource Control (RRC) protocol is known as ‘Layer 3’ in the AS protocol stack. It is the main controlling function in the AS, being responsible for establishing the radio bearers and configuring all the lower layers using RRC signalling between the eNodeB and the UE.



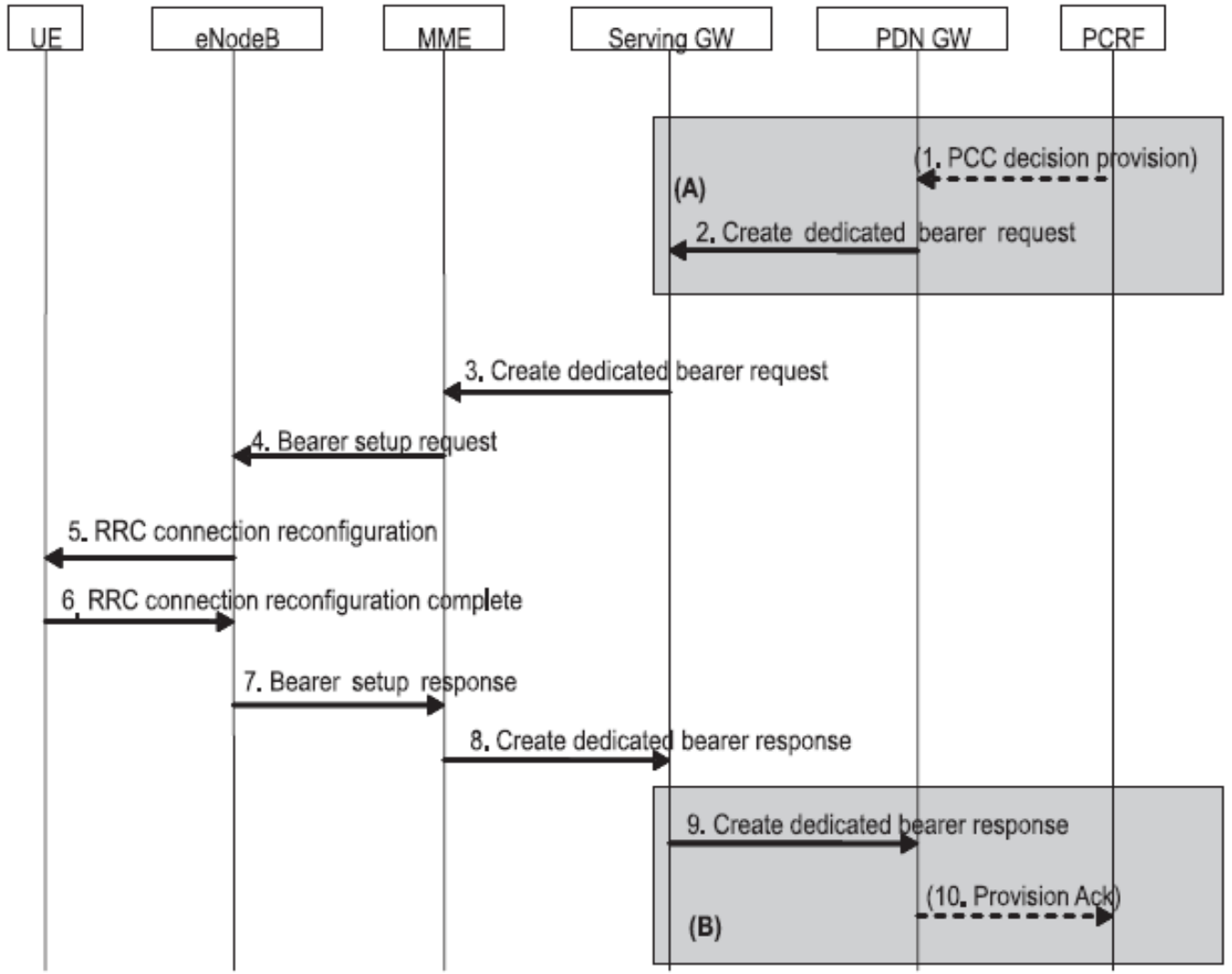
LTE: QoS

See specific QoS document

QCI	Resource type	Priority	Packet delay budget (ms)	Packet error loss rate	Example services
1	GBR	2	100	10^{-2}	Conversational voice
2	GBR	4	150	10^{-3}	Conversational video (live streaming)
3	GBR	5	300	10^{-6}	Non-conversational video (buffered streaming)
4	GBR	3	50	10^{-3}	Real time gaming
5	Non-GBR	1	100	10^{-6}	IMS signalling
6	Non-GBR	7	100	10^{-3}	Voice, video (live streaming), interactive gaming
7	Non-GBR	6	300	10^{-6}	Video (buffered streaming)
8	Non-GBR	8	300	10^{-6}	TCP-based (e.g. WWW, e-mail) chat, FTP, p2p file sharing, progressive video, etc.
9	Non-GBR	9	300	10^{-6}	

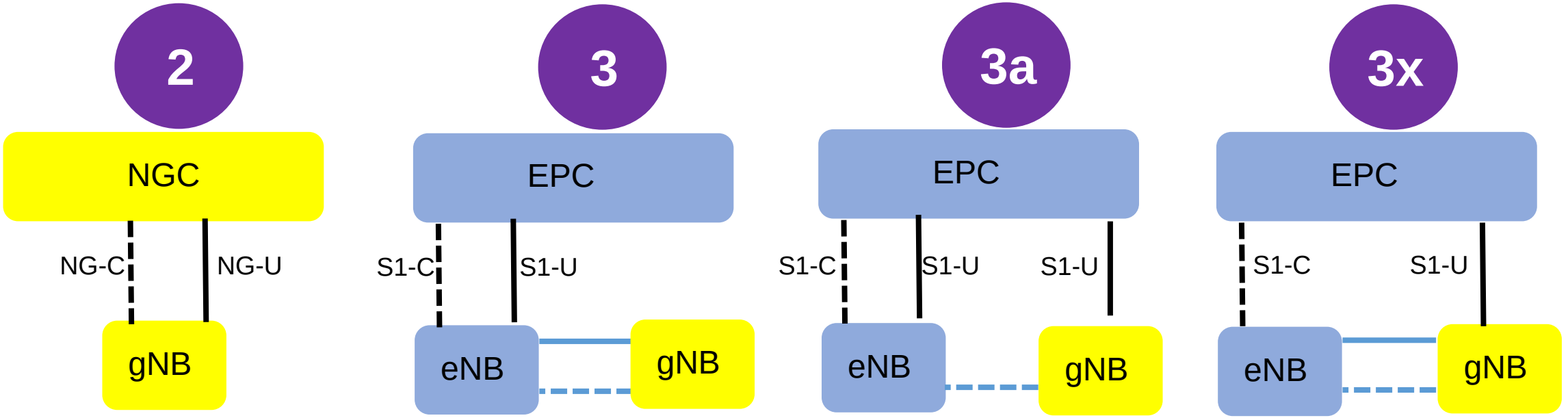
LTE: Bearer Establishment procedure

PCRF → 'PCC Decision Provision'
P-GW uses this QoS policy to assign the bearer-level QoS parameters.
P-GW then sends to the S-GW a 'Create Dedicated Bearer Request' including the QoS and UL TFT to be used in the UE.
S-GW forwards the Create DBR (including bearer QoS, UL TFT and S1-bearer ID) to the MME
MME builds a set of session management configuration information including the UL TFT and the EPS bearer identity, and includes it in the 'Bearer Setup Request' message which it sends to the eNodeB
Session management configuration is NAS information and is therefore sent transparently by the eNodeB to the UE.
Bearer Setup Request also provides the QoS of the bearer to the eNodeB; this information is used by the eNodeB for call admission control and also to ensure the necessary QoS by appropriate scheduling of the user's IP packets. The eNodeB maps the EPS bearer QoS to the radio bearer QoS. It then signals a 'RRC Connection Reconfiguration' message (including the radio bearer QoS, session management configuration and EPS radio bearer identity) to the UE to set up the radio bearer.



CONCEPTOS DE NSA

NSA OPCIONES DE INTERCONEXIÓN AL CORE



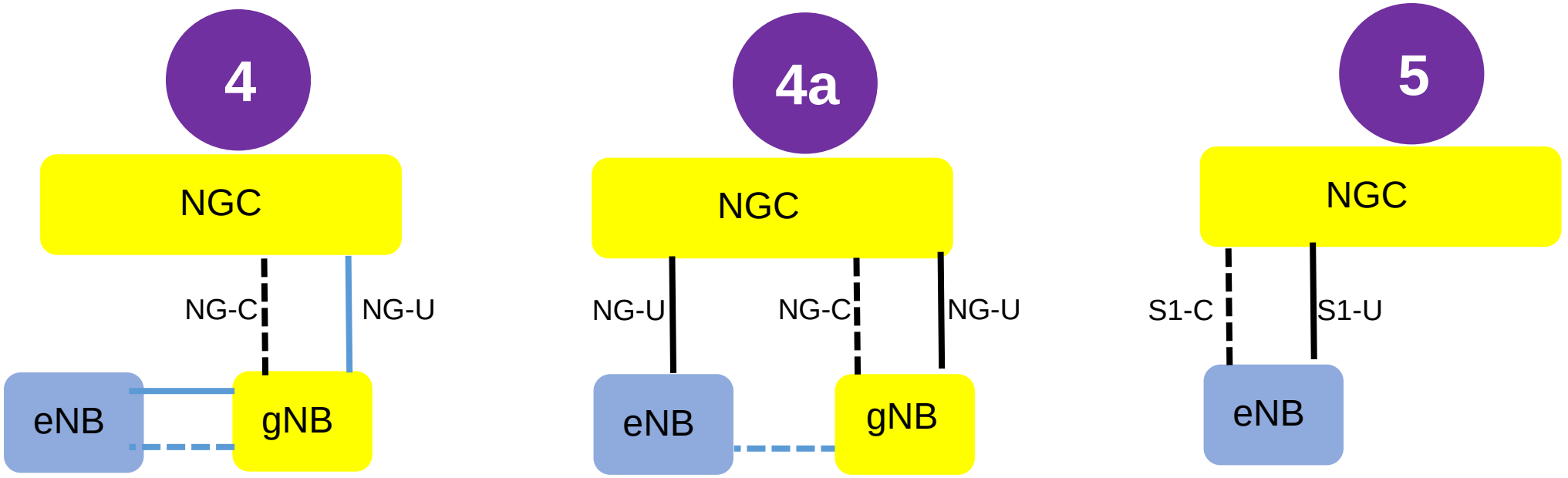
El EPC no reconoce el plano de control de NR, debe usarse la interfaz S1 de LTE
Aparecen variantes para el plano de Usuario

Analizar:

Plano de Usuario
Plano de control
Tipo de Core
Entidades de acceso que tributan

Existe la opción 1?

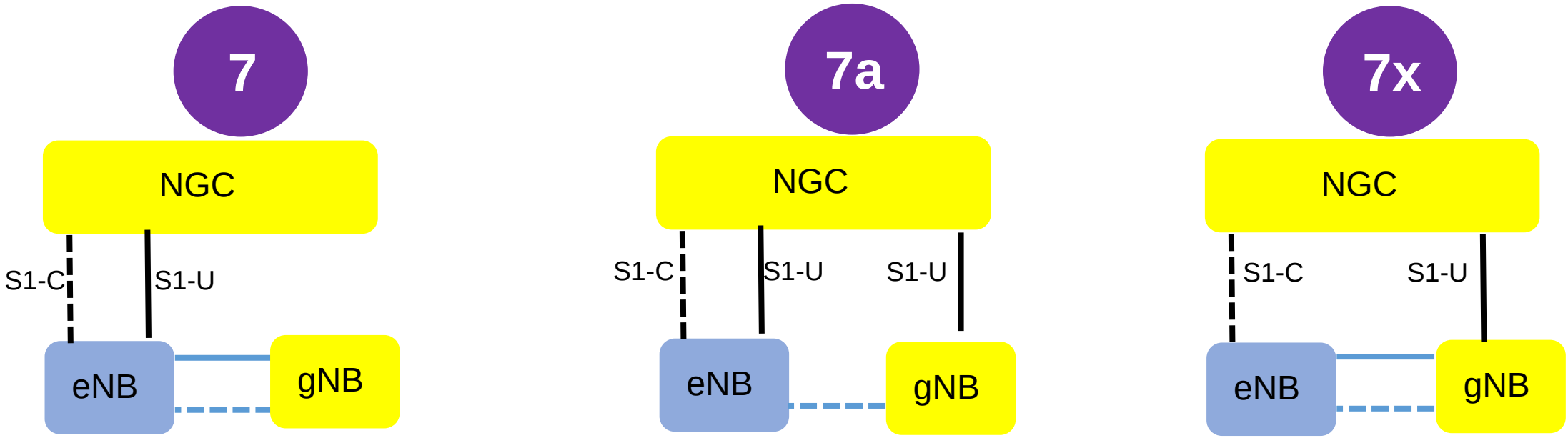
NSA OPCIONES DE INTERCONEXIÓN AL CORE



El NGC puede reconocer el plano de control de LTE, por eso ademite conexión con eNBs

Analizar:
Plano de Usuario
Plano de control
Tipo de Core
Entidades de acceso que tributan

NSA OPCIONES DE INTERCONEXIÓN AL CORE



Analizar:

Plano de Usuario

Plano de control

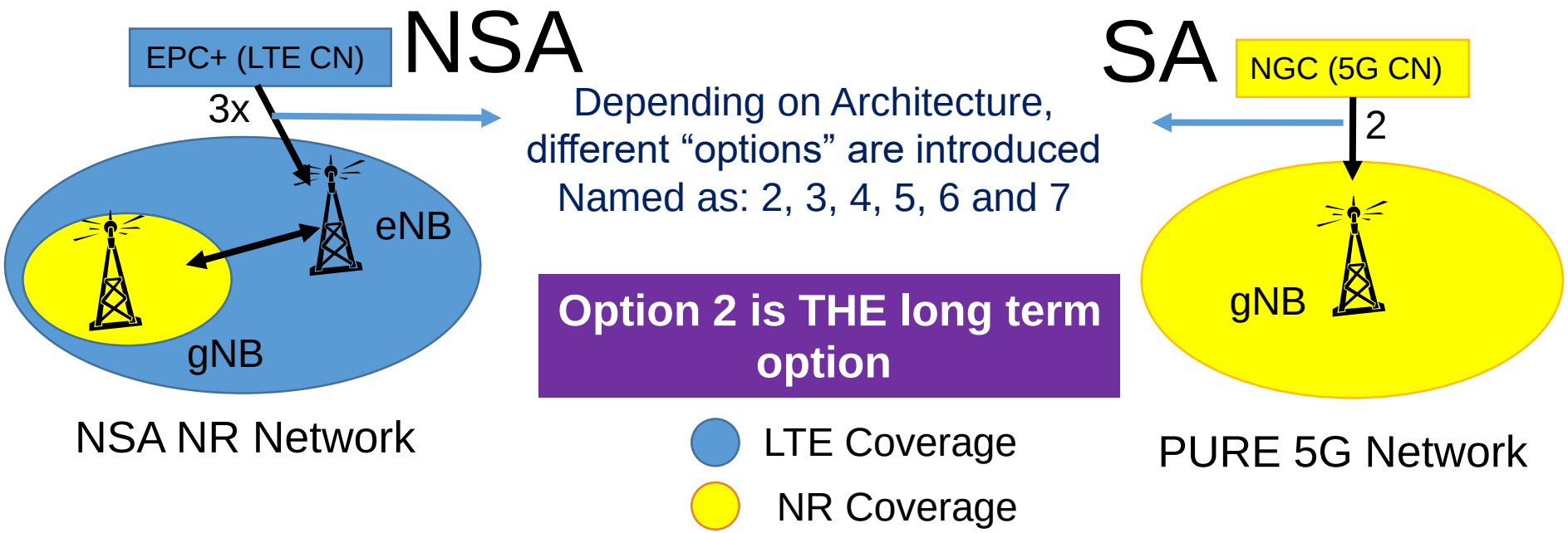
Tipo de Core

Entidades de acceso que tributan

OPCIONES DE INTERCONEXIÓN AL CORE

Analizar viabilidad de cada una de las opciones y focalizarse en las que realmente tienen chance de ser implementadas

CONSIDERACIONES DE ALTO NIVEL SOBRE LA CONEXIÓN AL CORE



NSA: 5G networks will be supported by existing 4G infrastructure.

The 5G Standalone (SA) network and device standard is still under review. The advantage of Standalone is simplification and improved efficiency, but availability date is its weakeness

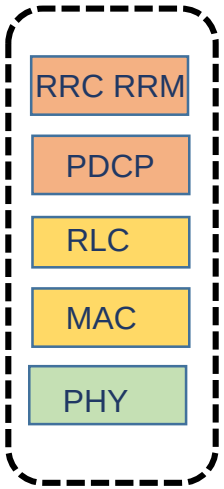
NR: Frequency Range 1 overlaps and extends 4G LTE frequencies, operating from 450 MHz to 6,000 MHz. Bands are numbered from 1 to 255 .

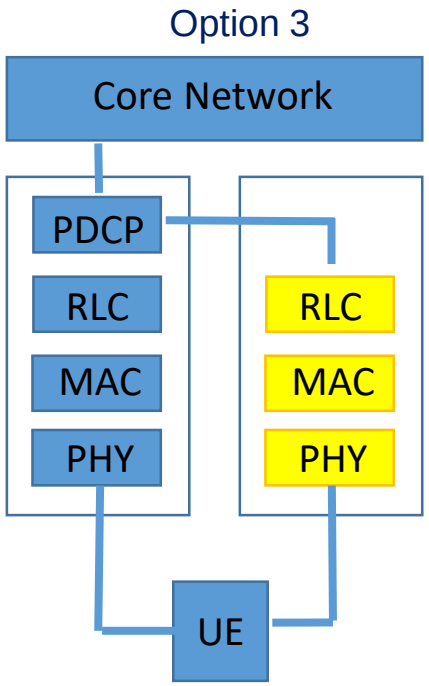
Millimeter wave (mmWave): Frequency Range 2 operates at a much higher 24,250 MHz (~24GHz) to 52,600 MHz (~52GHz). Bands are numbered from 257 to 511

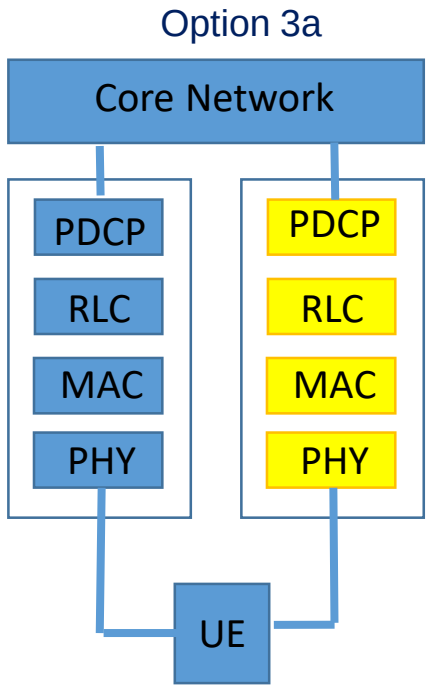
VARIANTES DE LA OPCION 3

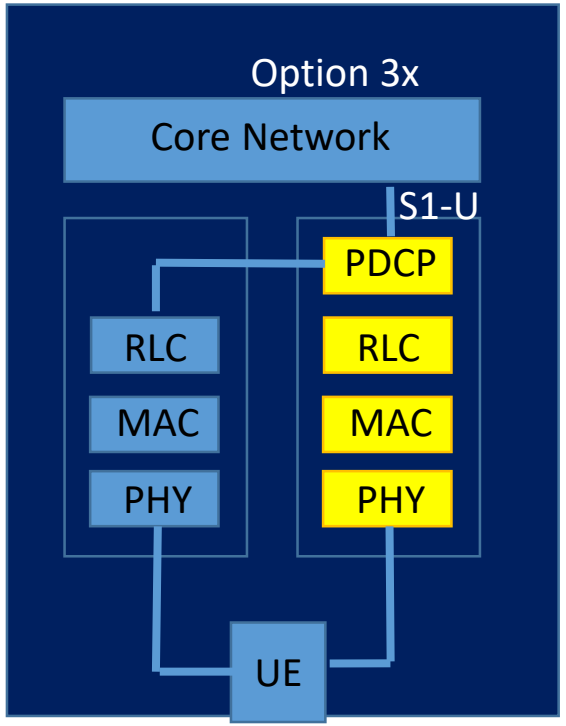
NSA options 3/3a/3x

3GPP Release 15 NSA NR operation is based on 3GPP Network Option 3 family which is “LTE assisted EPC Connected”. NSA options 3/3a/3x are as follows.









CP:
Allways existing
EPS LTE S1-MME

PDCP: Packet Data Convergence Protocol.

UP:
- Opt 3: LTE PDCP
- Opt 3a: separate LTE and NR PDCP.
- Opt 3x: NR PDCP

VARIANTES DE LA OPCION 3

Características comunes (CP)
- Se usa dual conectivity.
- El plano de Control es proporcionado por LTE

Diferencias importantes (UP)
- Opción 3: plano de Usuario es dividido en eNB
- Opción 3a: plano de Usuario es dividido en ePC
- Opción 3x: plano de Usuario es dividido en gNB

	CARACTERÍSTICAS	DESPLIEGUES POSIBLES
OPCION 3	Requiere mucho procesamiento en el eNB donde se hace el Split. El plano de usuario es anclado en el eNB lo cual reduce la interrupción en dicho plano (movilidad). No hay conexiones del gNB al Core	Solo se recomienda si no hay limitaciones de procesamiento en LTE
OPCIÓN 3a	El Split de datos puede ser ajustado en función de las condiciones de radio	No se recomienda, implica llegar a Core con dos interfaces para plano de usuario
OPCIÓN 3x	El Split de datos se hace en el gNB. No se requiere re-configuración en el eNB. Dependiendo de la cobertura, pueden suceder cambios de anclaje en el plano de usuario	Se recomienda en los estadíos iniciales de despliegue

NSA CONEXIONES DUALES

NSA. CONEXIONES DUALES

MCG: Master Cell Group
SCG: Slave Cell Group

MCG Bearer: Data Bearer en el lado MCG
SCG Bearer: Data Bearer en el lado SCG

MCG Split bearer: Data bearer Split desde el MCG
SCG Split bearer: Data bearer Split desde el SCG

Tipo de Bearer setup para cada opción

Opción 3: Setup MCG **Split** bearer

Opción 3a: Setup MCG bearer y SCG bearer

Opción 3x: Setup SCG **Split** bearer

- Dual Connectivity: UE está conectado al eNB y al gNB al mismo tiempo.
- Un nodo Master, otro nodo Esclavo
- Determinación del nodo Master o Esclavo depende del ancla del plano de control (la estación base que tiene un plano de control con el Packet Core es el nodo Master)

NSA ESTABLECIMIENTO CONEXION DUAL

El establecimiento de “Dual Connectivity” NSA es similar a la de Carrier Agreggation en LTE

Paso 1: El UE realiza el acceso inicial en el lado eNodeB, y el eNodeB ofrece una configuración de medición 5G basada en las capacidades del UE.

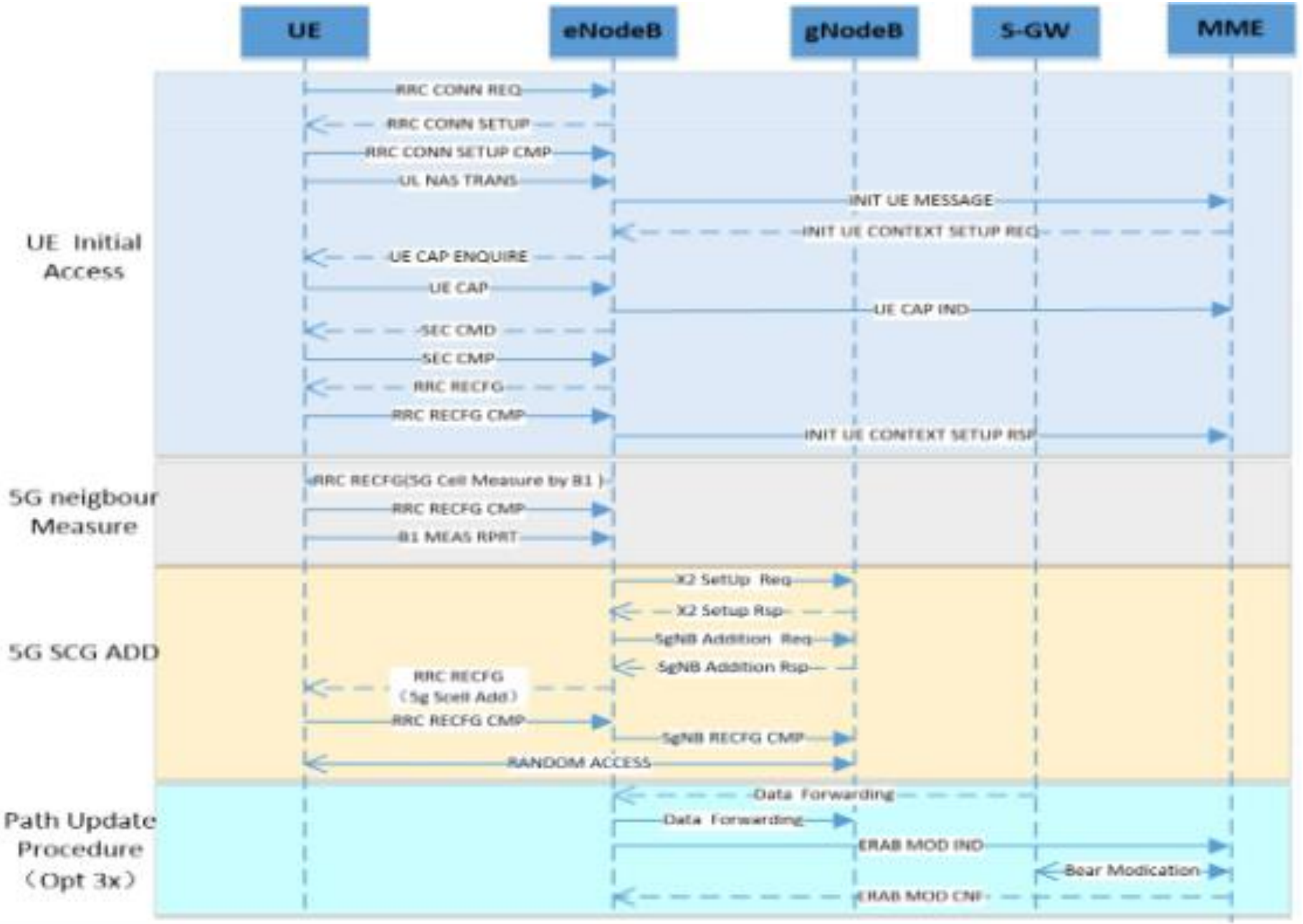
Paso 2: El UE realiza la medición 5G . Cuando se cumple el evento correspondiente (A1 A2, A4, etc) el UE informa al nodo Master.

Paso 3: El eNodoB inicia un procedimiento de adición de celdas NR al gNB basado en la información sobre la celda 5G disponible en el nodo Master. Si no hay una interfaz X2 disponible, el eNodeB necesita establecer una interfaz X2 primero.

Paso 4: El gNB toma la decisión de admisión de recursos. Si la admisión es exitosa, el gNB envía la información de configuración de la celda secundaria al eNodoB. El eNodeB entrega la configuración a través del mensaje RRC para completar la configuración de SCell.

Paso 5: En la arquitectura Option3x, el plano de usuario debe cambiarse y el portador S1-U se cambia del eNB al gNB.

NSA ESTABLECIMIENTO CONEXION DUAL



POSIBLES CASOS DE EVOLUCIÓN

Paso 1, año 1, dependencia de terminales existentes y estado del arte de 5G (start on dedicated nodes)
NSA only. (NSA puro, con NR integrado al EPC+).
SW upgrade en el EPC (MME, S/PGw-C, S/PGw_U, HSS, PCRF).
Soporte de NR
No se trata de un scenario de overlay nGC, es solo un ePC+

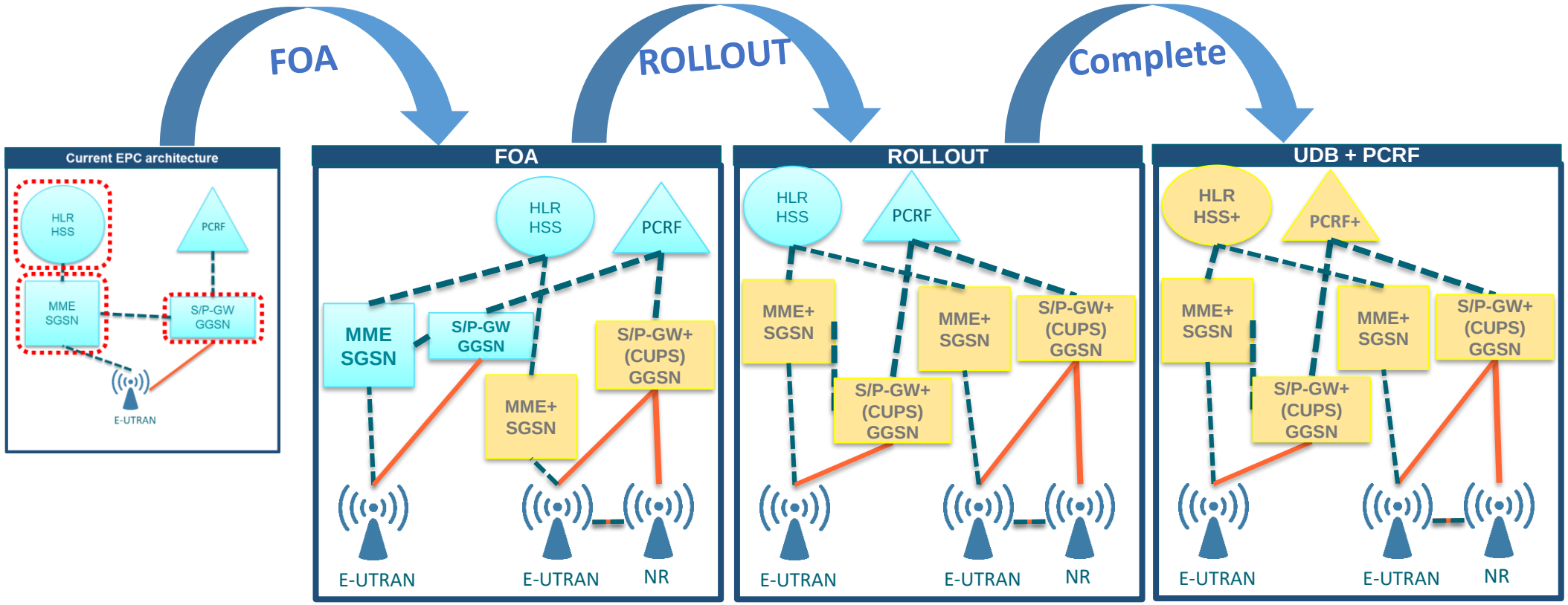
Paso 2, año 2 y año 3
NSA +SA. (NSA solo para integración inter Core, a través de la interface N26)
2G/3G/4G/5G en un Core común (**nGC),** modo overlay del ePC+.
Sigue habiendo un ePCC+ (NSA) y también un nGC (NSA&SA) is agregado. La introducción de un nGC, implica nuevas entidades, y nuevas interfaces. Pueden existir diferentes fases en la evolución dell nGC.

Paso 3, siguientes años (puede ser desde el inicio si se omiten los anteriores)
2G/3G/4G + 5G NSA + 5G SA. Todo el trafico es controlado por el Nuevo Core comúne.

La elección de NSA Vs SA depende de muchos factores, en especial de la fecha de lanzamiento, el estado del arte de la tecnología, la escala de despliegue y el soporte de terminales entre otros factores.

POSIBLES CASOS DE EVOLUCIÓN-Paso1

Select technology/vendor to deploy NSA 5G Core.
Select **a pair** of MME in cluster and upgrade them
Link them with 5G RAN zone (eNB & gNB)
Select a pair of S/PGw and upgrade them (using CUPS)

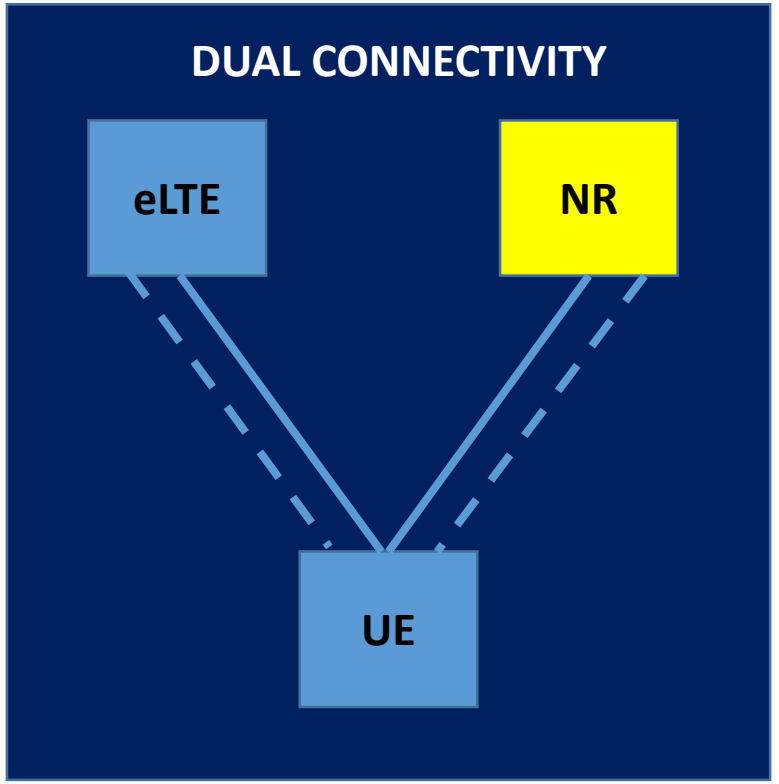


DUAL CONNECTIVITY
DSS
CARRIER AGGREGATION

DUAL CONECTIVITY

Option 3, 3a and 3x, are based on LTE dual connectivity (DC) concept.
DC means that UE is in connection with more than one RAN. Master and Secondary eNB: MeNB & SeNB.
When DC concept include múltiple RAT (in our case LTE &NR), it can be applied to 5G

LTE dual connectivity (it is not the same as Carrier Aggregation)
In Dual Connectivity, the split bearer concept is introduced, in which a data bearer is split between the two eNBs, at the PDCP layer. The PDCP layer at the anchoring User Plane node is responsible for the PDU numbering, distribution between master and secondary eNBs, aggregation, sorting and in-sequence delivery to upper layer.
For example, MeNBs can be designed to handle the UE connectivity and the SeNBs to be activated **only** when there is data to be transmitted, which would decrease SeNBs' power consumption.



DUAL CONECTIVITY

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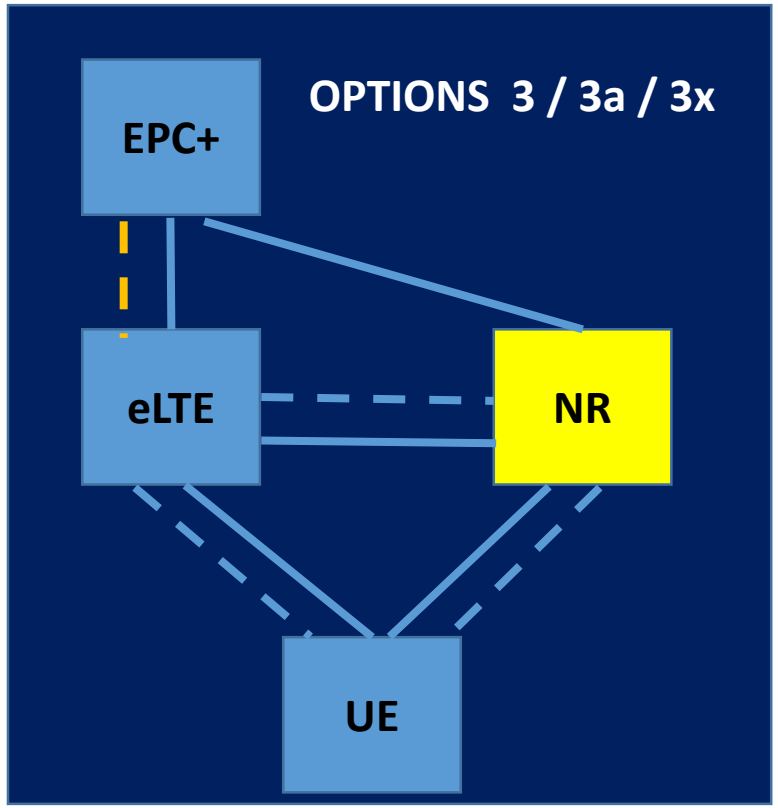
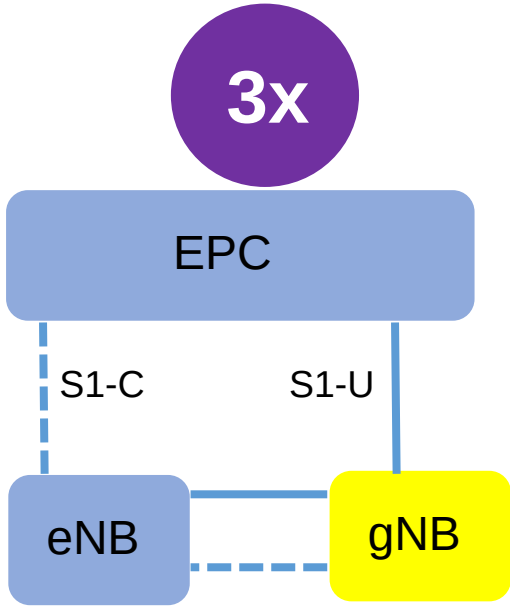
Option 3
Option 3 family uses for Control Plane (CP) the RRC from LTE (no RRC from NR is used).

Main difference between all of “option 3 family options”, is related to UP.
In case of ***3x option***, ***NR PDCP layer is used*** thus avoiding the bottleneck of the Option 3 (which uses LTE PDCP), but of course it is more demanding to the eNB compared to 3a since it needs to support NR UP interworking.





DSS

En 5G, dejamos de hablar de LTE? → NO → Hay cambios en LTE? → LTE+ / NR

In 3GPP, the 5G radio access roadmap is comprised of two tracks. One is based on the evolution of Long Term Evolution (LTE) and the other on New Radio (NR) access. In the LTE track, enhancements are still ongoing in order to support as many 5G requirements and use cases as possible. The NR track, on the other hand, being free from the backward compatibility constraints of LTE.

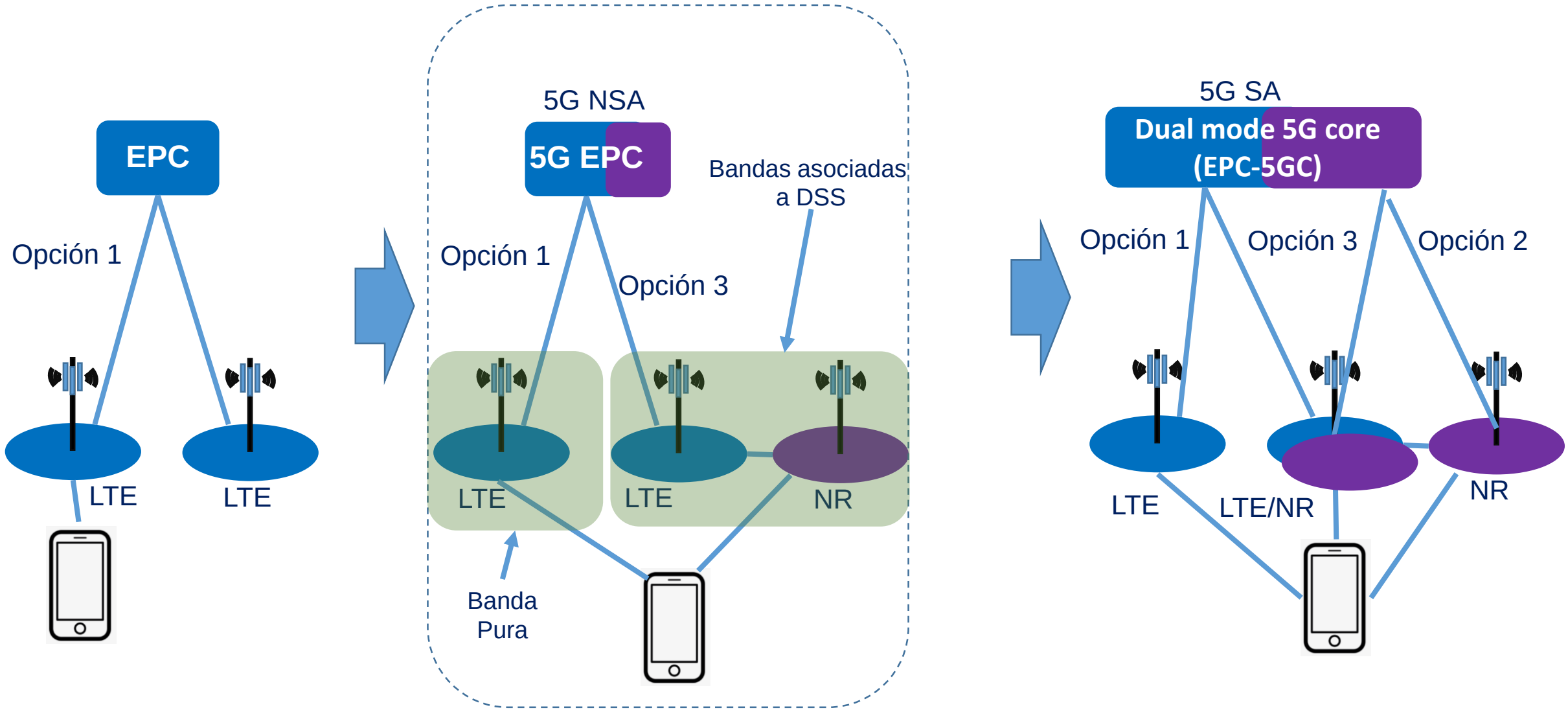
RECURSOS/ ASPIRACIONAL DE 5G

- Mayor capacidad (y velocidad de datos)
- mm-Wave
- Diferentes numerologías
- Slicing de red
- Split de arquitecturas
- Sistema completo de NR (radio), Núcleo de Red (Core)
- Otros componentes de apoyo (PCF,AMF).

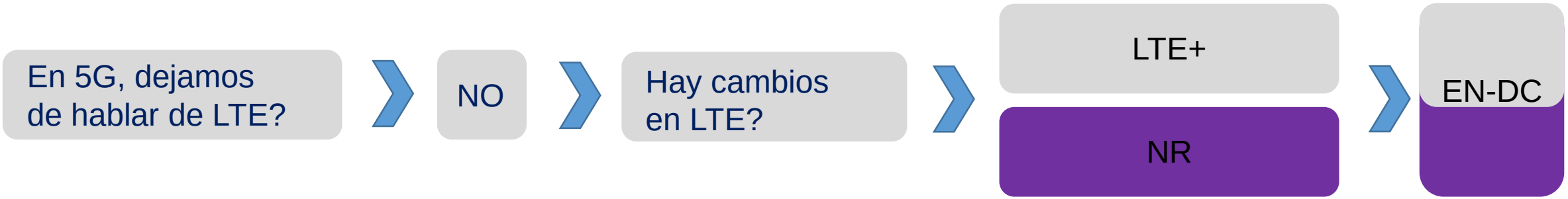
Como bajar el TCO y hacer una migración mas rápida a la vez?

Cobertura 5G Vs experiencia de Cliente

DSS


EPC
Opción 1
LTE
LTE
5G NSA
5G EPC
Bandas asociadas a DSS
Opción 1
Opción 3
LTE
LTE
NR
Banda Pura
5G SA
Dual mode 5G core (EPC-5GC)
Opción 1
Opción 3
Opción 2
LTE
LTE/NR
NR

DSS

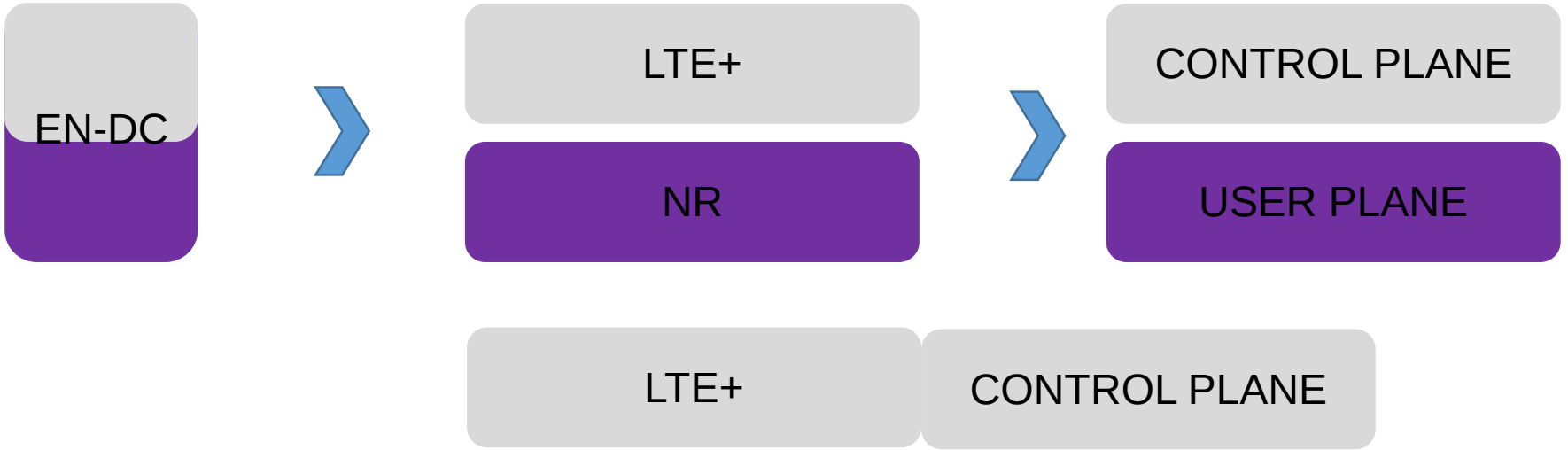


Para tener un despliegue rápido de redes 5G sin esperar necesariamente a que se complete el sistema NR completo ,3GPP ha especificado el sistema de interfuncionamiento estrecho LTE-NR completo en marzo de 2018. En el interworking de NR y LTE, una versión de NR (NSA) se utilizará junto con LTE en un modo de conectividad dual (DC), donde ambas tecnologías están conectadas al LTE Evolved Packet Core (EPC). Esta estrecha interacción entre LTE y NR es lo que se conoce como Conectividad dual E-UTRAN NR (EN-DC).

En el caso de EN-DC, esta es la primera vez que se habilita un escenario de DC para dos tecnologías de acceso de radio 3GPP ***diferentes***. Dado que los componentes y las capacidades de la tecnología subyacente no son los mismos para LTE y NR, ha habido una serie de desafíos que resolver antes de completar la primera versión de NR en 3GPP Release 15.

La expectativa original de 3GPP en 2018 Vs lo que realmente está ocurriendo

DSS



En la configuración general de EN-DC, LTE es la tecnología primaria que controla la conexión de radio de un equipo de usuario (UE) a través de la interfaz de aire, así como la conexión del plano de control al EPC.
NR, en cambio, proporciona una capacidad mejorada al UE a través de la nueva interfaz de aire y (*opcionalmente)* un enlace de plano de usuario directo al EPC.

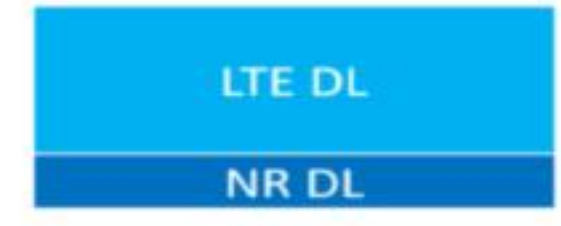
Ese “opcionalmente”, se cumple en nuestros escenarios?

EN-DC: E-UTRA - NR Dual Connectivity (3)
NE-DC: NR - E-UTRA Dual Connectivity (4)
NGEN-DC:Next Generation-RAN E-UTRA-NR Dual Connectivity, (7)

(D)SS

Spectrum sharing can be implemented in both Frequency and/or Time. They are for main sharing schemes, namely:

- Static sharing in Frequency – The channel is split into discrete frequency portions for LTE and revised every 1ms.
- Static sharing in Time – The entire channel is available to LTE or NR for a portion of time
- Dynamic sharing (DSS) – The channel is dynamically split in frequency according to LTE or NR demand (with limited granularity), and the split is revised every 10ms (time division)
- Instant sharing (ISS) - The channel is split in frequency with **PRB** level granularity according to LTE or NR demand, and the split is revised every 1ms.



Static SS in Frequency

Static SS In Time

Dynamic SS

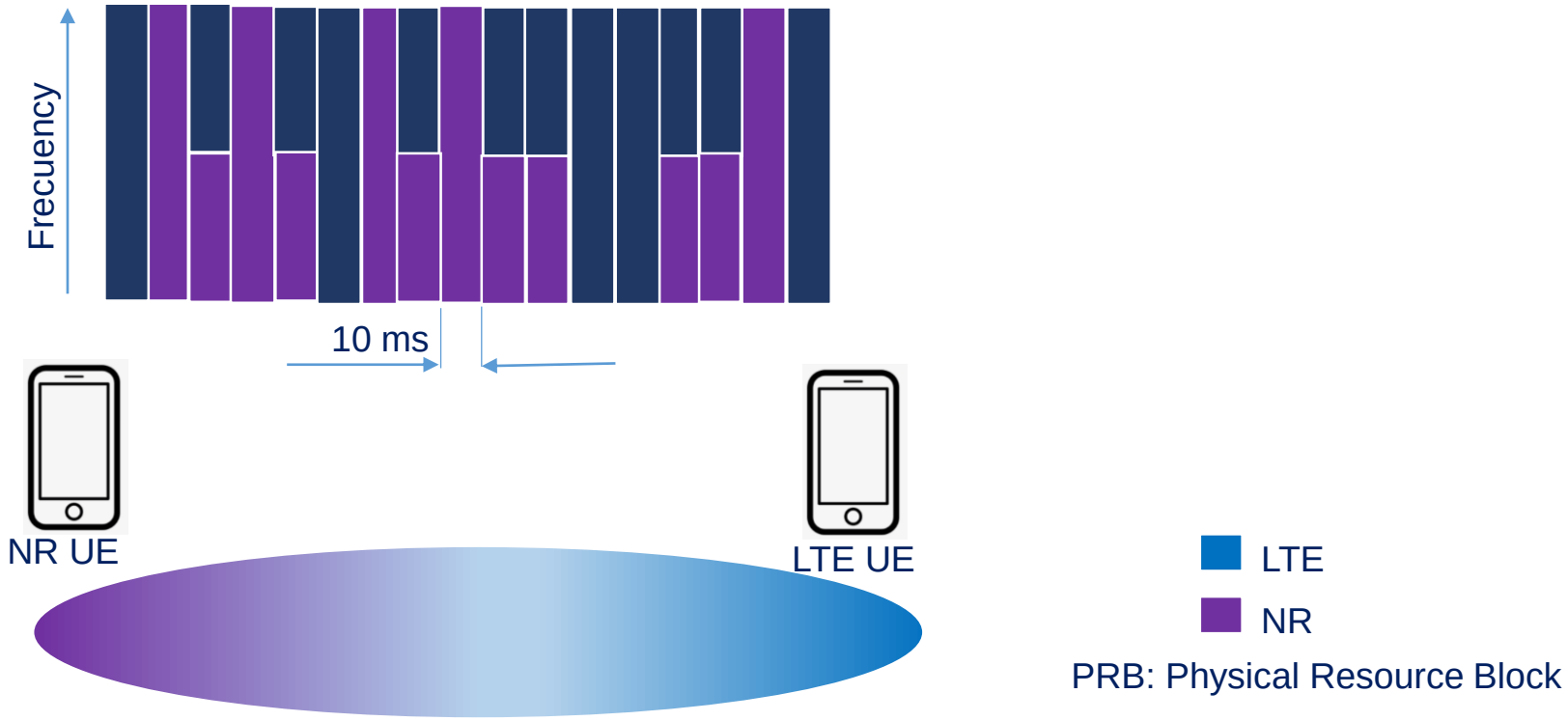
Instant SS

DSS DINAMIC SPECTRUM SHARING

In Dynamic Sharing, the channel is dynamically split in the frequency (PRB) domain between LTE and NR according to buffer loads in the eNodeB, gNodeB and UEs (‘demand’). The following PRB ratios are supported:

- 100% PRBs for NR
- 50% LTE & 50% NR
- 100%LTE

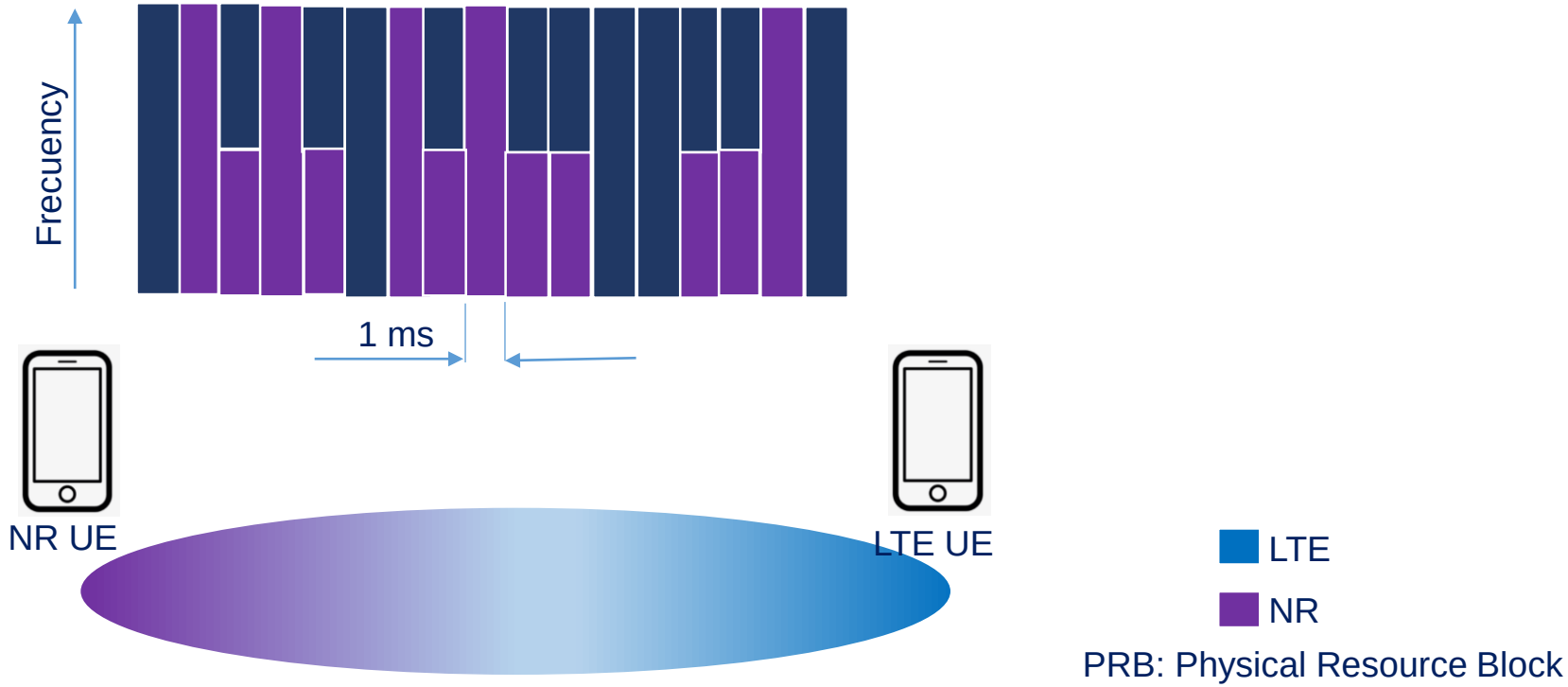
The LTE and NR demand is reviewed every **10ms** and the PRB ratio changed accordingly.



ISS INSTANT SPECTRUM SHARING

In instant spectrum sharing the resolution of both frequency (PRB) and time is increased. In ISS, it is possible to assign individual PRBs according to LTE and NR demand. The allocation of PRBs is then reviewed and updated every **1 ms.**

Due to the improved resolution in both frequency and time, ISS will provide greater throughput and reduced latency when compared to DSS.



¿Es posible revisar la asignación cada períodos menores a 1 ms?

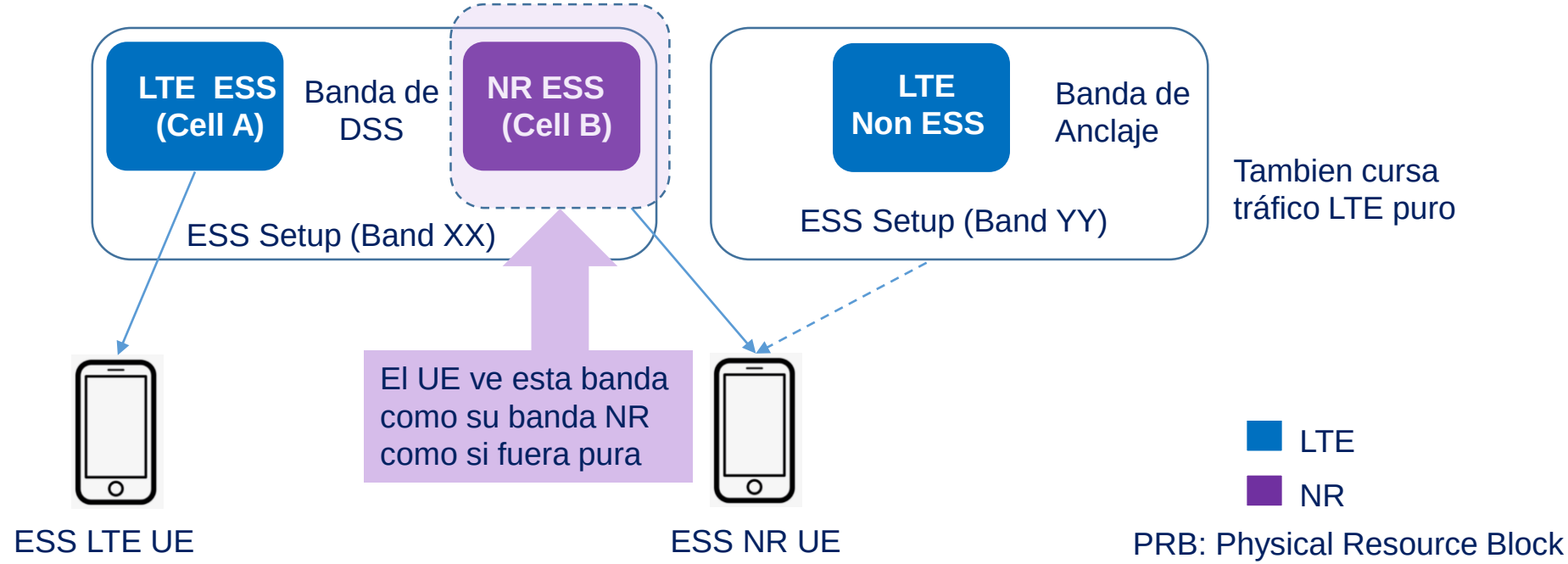
DSS & ISS

The deployment of ESS enables the use of NR in two 3GPP options / configurations:

- Option 2: Standalone (SA)
- Option 3: Non-Standalone (NSA)

Due to timing limitations in the broadcast of synchronization channels, in order to use ESS NR NSA, a **separate Non-ESS LTE anchor cell is required**.
Cell C is configured in a different band to Cells A and B.

Normalmente
nos referimos
al eNB o gNB
como una unidad
pero las configuraciones
a nivel de RRU /BBU
son mas complejas
de lo que la teoría suguiere



¿Por qué en la Banda de DSS aparecen dos portadoras, una de LTE y otra de NR?

DSS & ISS

El eNB publica en los SIB, las bandas que usa para CA y DC , entre otros.
Con la informac del eNB, el UE a la hora de informar capabilities puede hacer un filtro para achicar el reporte.
Si por error de configuración el eNB no anuncia una banda, el UE la descartará

El UE se conecta al ancla, ese ancla anuncia por Broad la disponibilidad de NR
El ancla además establece las condiciones u umbrales de NR. Para DC se usa evento B3 (medición de umbrales de nodo de NR)

Capabilities del UE. Luego el eNB genera la señaliza para hacer el agregado de NR
DC debe estar permitido en el eNB y soportado por el UE (debe ser incluid en el reporte del capabilities del UE)

UL trae aparejado problemas de potencia. El UL se reparte en ambas conexiones. También puede subir datos por el uplink del CP.
El UE determina si en e UL , va a usar SC-FDMA (potencias altas modulac baja) o bien OFDMA (buen enlace).
OFDMA mejora tasa de errores pero no siempre es posible. El SC tiene limitaciones por lo de los recursos disontínuos, por eso se prefiere OFDMA
DSS es un complemento de UL. La elección de la banda de anclaje baja o media, dependerá en gran medida de las preferencias de UL.Las bandas altas tienen problemas en UL (pérdidas). Si mantengo UL en bajo tengo mejor performance.

CePETel
Sindicato de los Profesionales de las Telecomunicaciones
SECRETARÍA TÉCNICA
IPEI
Prof. José Luis Pellegrino

DSS & ISS

- Se descarta la división estática. Se deben optimizar recursos ya que la demanda 5G crece lentamente
- Una banda configurada como anclaje exclusivamente (ej.: 2600).
- En banda de DSS: 3 celdas primarias (LTE), 3 celdas secundarias (NR).
- El scheduler, dinámicamente comparte LTE y NR
- El dispositivo recibe NR y LTE
- Si se dispone de otras bandas, se puede usar además CA, pero solo se usa una banda para DSS.
- En NSA sin DSS, tendría una banda exclusiva para LTE (ej.:700) y otra NR (j.:3.5G)

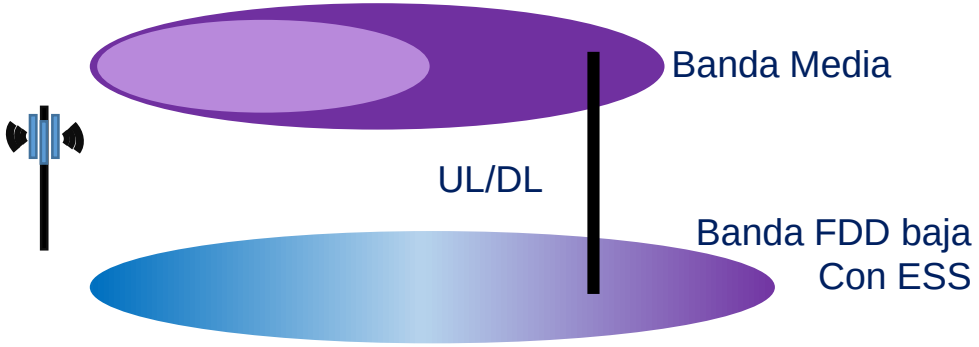
Ejemplo: DSS en 2.6 & 3.5.
DSS: 3.5 GHz anclaje: 2.6 GHz CA: 700 MHz

VENTAJAS

- ❖Capability of instantenous 1ms sharing between NR and LTE
  - ●Adaptive to real-time traffic variations
  - ●Capability of FDM based sharing
  - ●Secured QoS for latency sensitive applications
- ❖No need for dedicated NR Baseband, Radio or Transport
- ❖No need for new CPRI link

USO DE CARRIER AGGREGATION CON NR

Aumento de cobertura con Carrier Aggregation

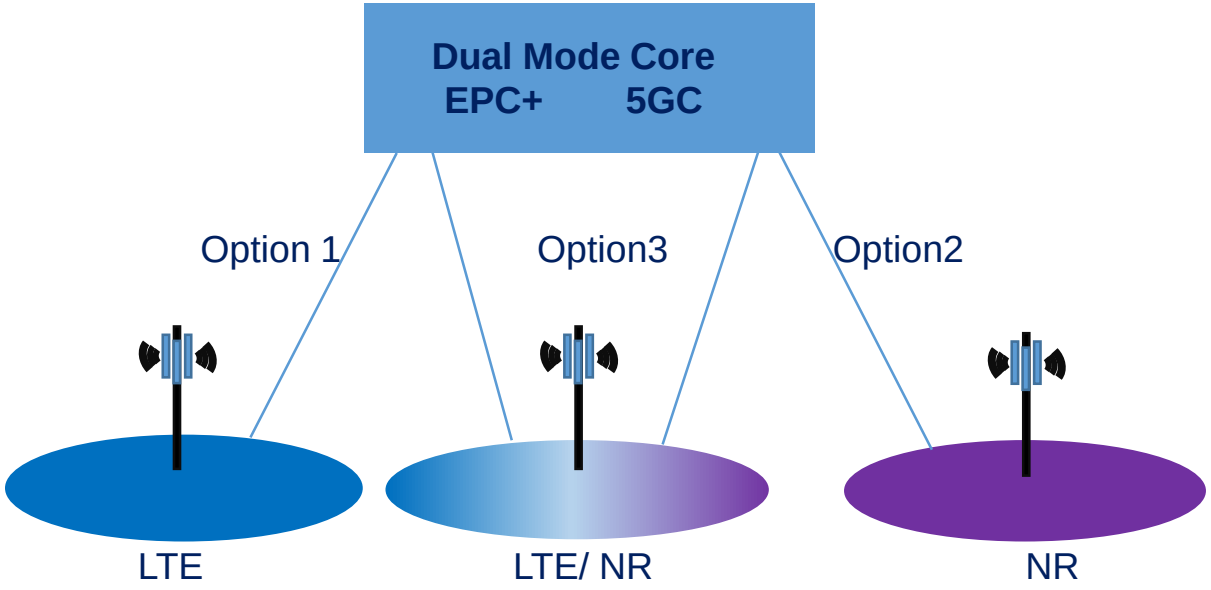


NR mejora la eficiencia espectral y la latencia de RAN

- Mayor utilización de espectro (guardas)
- Mas flexibilidad de overhead
  - Control Channel (CCH)
  - Reference Signal (RS)
- Menor latencia

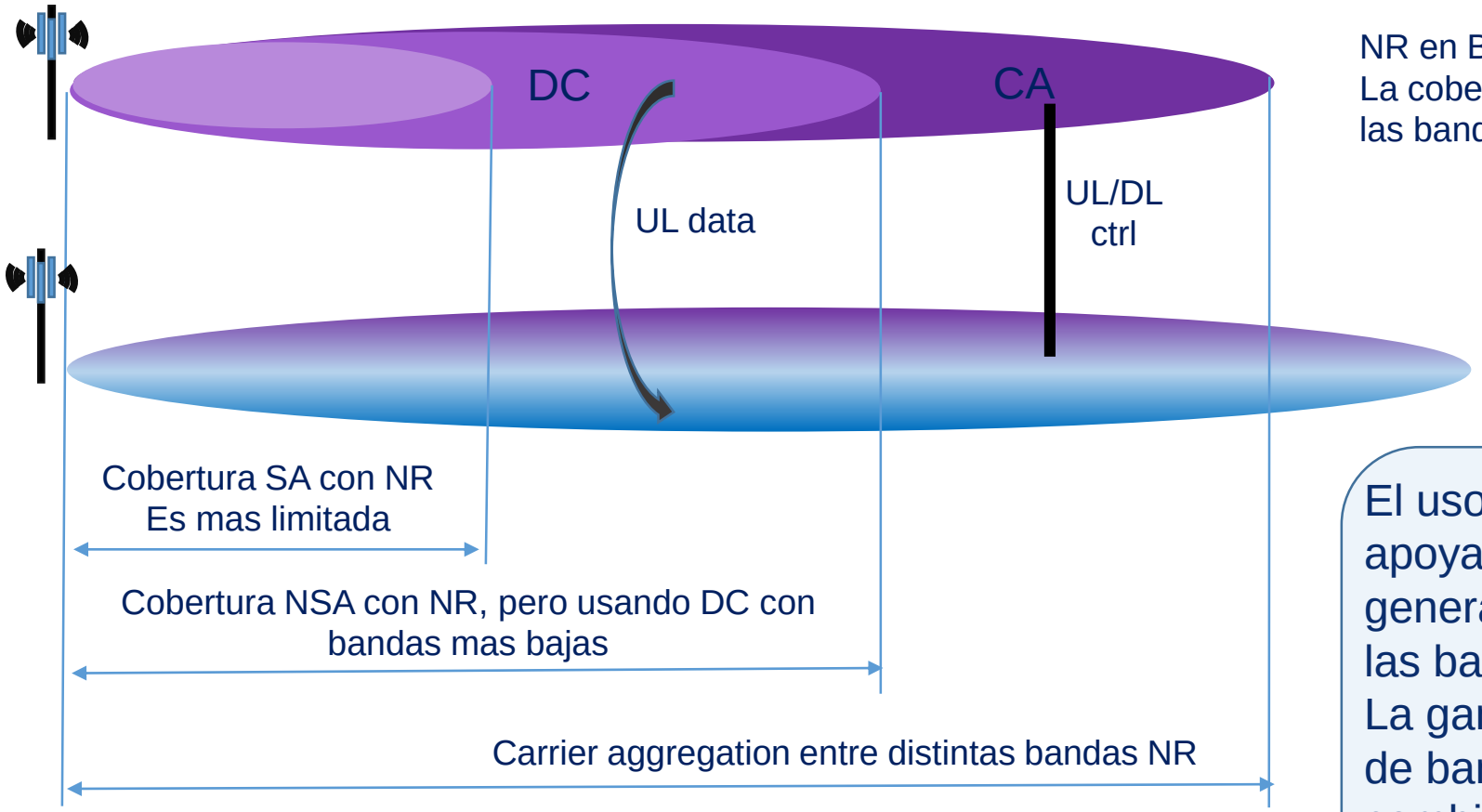
El efecto se potencia con el ancho de banda

Cobertura SA con 5G FDD, baja la complejidad



USO DE NR EN BANDAS FDD

Las bandas FDD usadas para extender la cobertura de bandas TDD



NR en Banda Media TDD (ie 3,5 GHz)
La cobertura se aumenta apoyándose en las bandas bajas

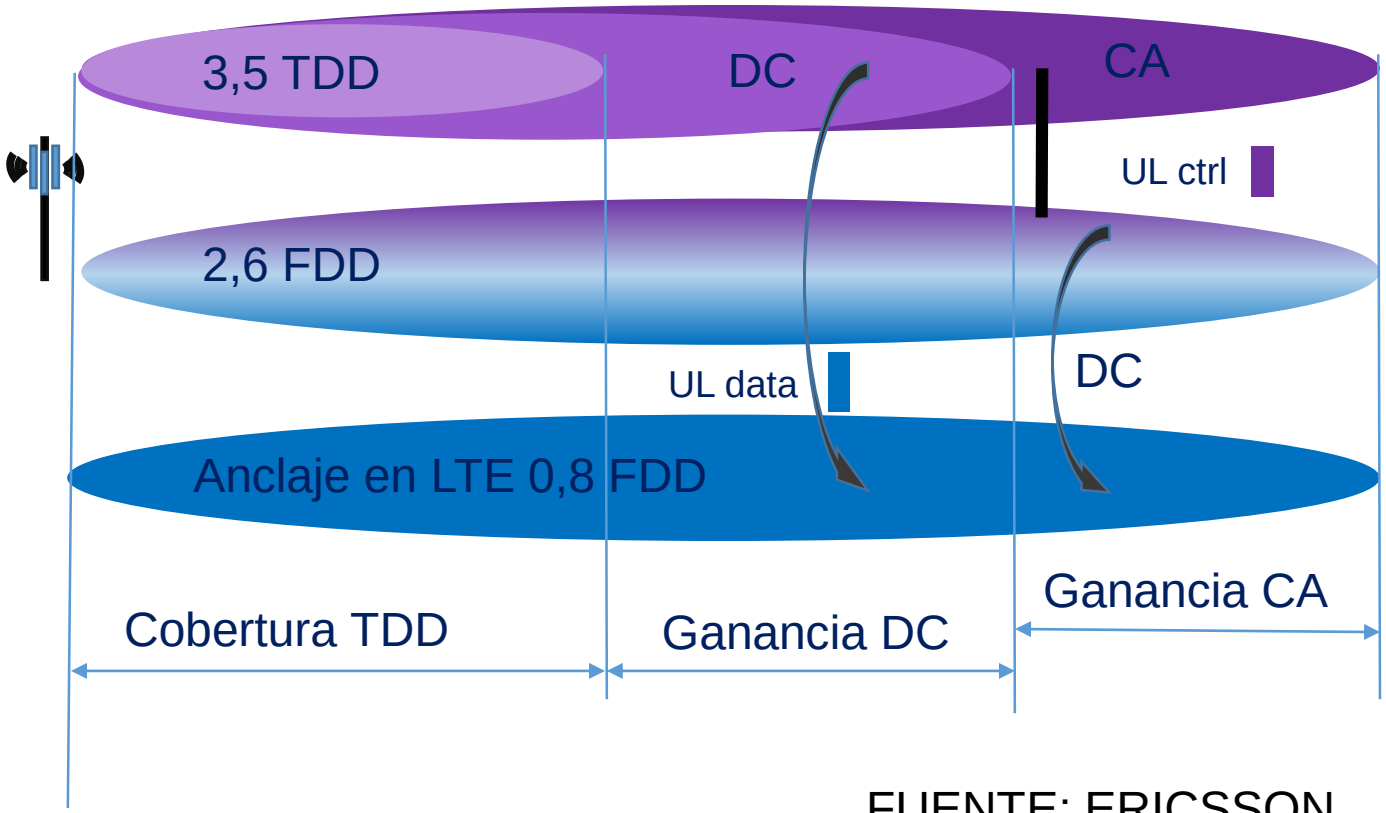
NR/LTE FDD usando ESS/DSS (bandas bajas)

El uso de técnicas de DC y/o CA al apoyarse sobre bandas de anclaje por lo general mas bajas mejora la cobertura de las bandas medias.
La ganancia depende de la combinación de bandas usadas (no todas las combinaciones funcionan bien), pero puede llegar a 7-9 dB

FUENTE: ERICSSON

Refexionar sobre FDD Vs TDD, LTE Vs NR, bandas bajas Vs bandas medias, cobertura Vs capacidad

DC & CA USANDO LAS BANDAS DE 0,8, 2,6 Y 3,5



FUENTE: ERICSSON

TDD PURO NR en Banda Media
UL/DL (datos y ctrl) en NR 3,5 GHz TDD

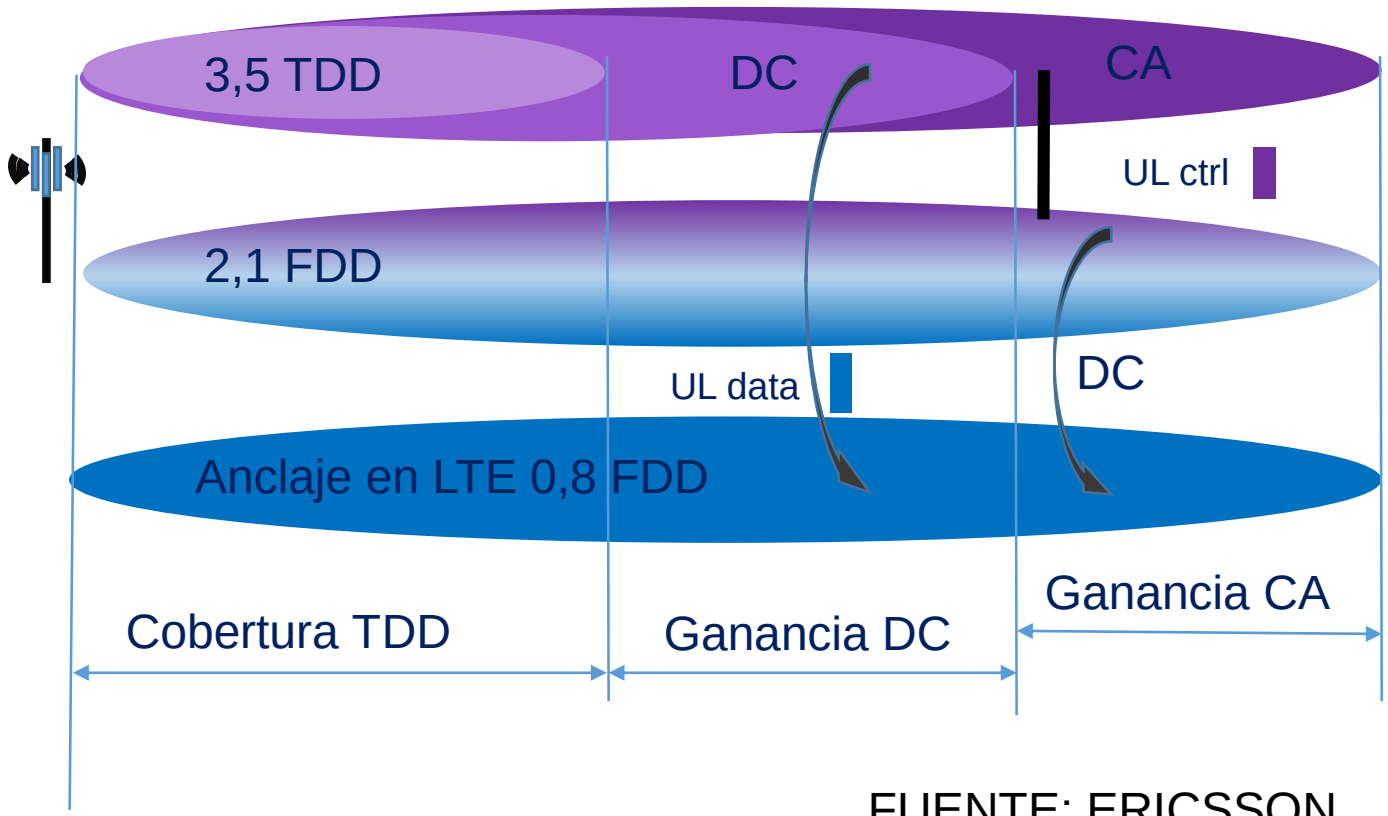
EN-DC (L800 + NR TDD 3500)
UL data en la banda anclaje L800
DC comparte energía entre bandas, el UE trabaja con menor consumo

EN-DC con NR CA (L800 + ESS2600 + NR TDD 3500)
UL data en la banda anclaje L800
UL de control en ESS2600 NR
DC comparte energía entre bandas, el UE trabaja con menor consumo

Para mayor ganancia se recomienda usar un orden mMIMO 64T64R en 3,5

Refexionar sobre la elección de bandas para cada función

DC & CA USANDO LAS BANDAS DE 0,8, 2,1 Y 3,5



FUENTE: ERICSSON

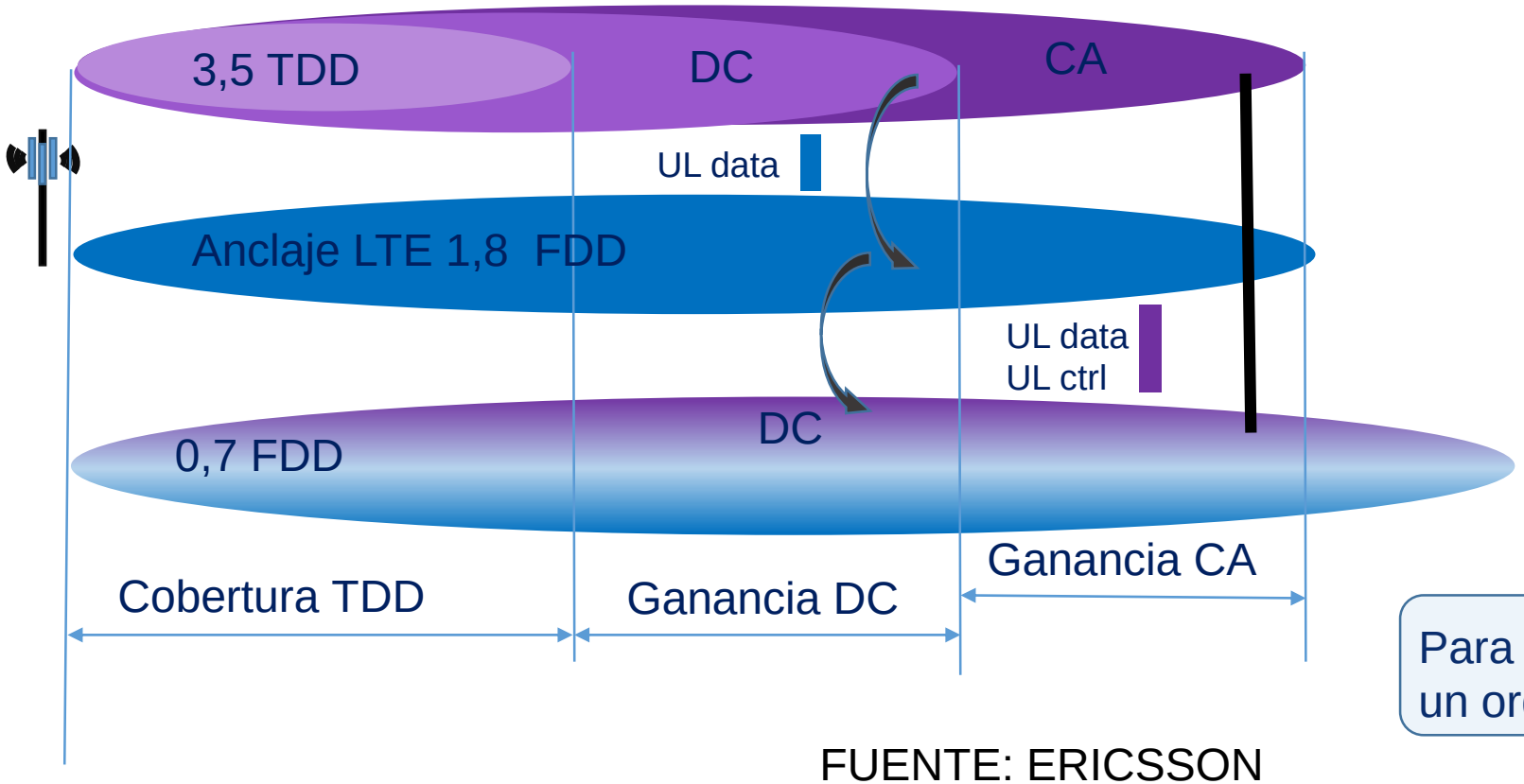
TDD PURO NR en Banda Media
UL/DL (datos y ctrl) en NR 3,5 GHz TDD

EN-DC (L800 + NR TDD 3500)
UL data en la banda anclaje L800
DC comparte energía entre bandas, el UE trabaja con menor consumo

EN-DC con NR CA (L800 + ESS2100 + NR TDD 3500)
UL data en la banda anclaje L800
UL de control en ESS2600 NR
DC comparte energía entre bandas, el UE trabaja con menor consumo

Para mayor ganancia se recomienda usar un orden mMIMO 64T64R en 3,5

DC & CA USANDO LAS BANDAS DE L1800, ESS700 Y NR TDD 3500



TDD PURO NR en Banda Media
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UL data en la banda anclaje L1800
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EN-DC con NR CA (L800 + ESS2100 + NR TDD 3500)
UL data en ESS 700 NR
UL de control en ESS 700 NR
DC comparte energía entre bandas, el UE trabaja con menor consumo

Para mayor ganancia se recomienda usar un orden mMIMO 64T64R en 3,5

FUENTE: ERICSSON

DSS- Rol de las bandas FDD en 5G

Wave 1

NSA

- **5G NSA** mode has the **support of LTE** bands by means of EN-DC for:
  - **Aggregating throughput** of 5G NR band and LTE bands through EN-DC mechanism
  - Having **smooth mobility** when 5G NR coverage is not mature enough
  - **Coverage extension of 5G NR 3,5 GHz band:** due to UL from LTE FDD band support in EN-DC mechanism (*)

Wave 2

SA

- For having support from **FDD** bands in **5G SA,** it is important to have **5G NR in current LTE FDD bands** in order to:
  - **Aggregated throughput:** 5G NR 3,5 GHz + current LTE FDD bands **Carrier Aggregation**
  - **Coverage Extension:** Extend the coverage of 5G NR 3,5 GHz DL by means of 5G NR FDD band UL with Carrier Aggregation. Carrier Aggregation will help to extend outdoor coverage but it will be a mechanism for having deeper indoor coverage in TDD Band
  - **Smooth Mobility**: for having continuous 5G coverage

FDD Bands could be available for 5G NR by means of Dynamic Spectrum Sharing

(*) with 5G NR in FDD can be extended a bit more (depending on the bands selections)
EN-DC: E-UTRAN-NR Dual Connectivity

DSS

NSA

- Rapid roll-out of 5G coverage (**5G Logo quick increase**)
- Depending on the band combinations for LTE anchor for DSS, DSS may bring an **extension of the C-Band 5G coverage by means of CA**, on top of EN-DC gain. In EN-DC, **NR UL** Data can be moved to *LTE FDD* to extend DL coverage. In CA, not just **NR UL** Data can be move to FDD band but UL L1 control channels can be moved to NR FDD as well -> **additional gain with respect to EN-DC**

SA

- DSS will enable more 5G FDD bands for different purposes related to CA:
  - **Extension of C-Band DL coverage** maintaining UL data through the low FDD band, if DSS is the only option for getting a 5G FDD band
  - **CA of existent FDD bands** to maintain at least the **same level of performance in SA than in NSA**. Bear in mind that in some indoor opportunities only low bands can penetrate and then the 4G experience through the aggregation of several bands may be better than one single 5G FDD band.
- **Helping congested LTE low bands through new 5G low bands like 700 MHz.** At the beginning of the 5G launch, the 5G traffic is expected to be very low whilst 4G traffic in L800 is extremely loaded and the most efficient way to offload that traffic in indoor environments is with other low band, **getting the most of the new 700 MHz band**.

Impact on network strategy of band combination 700-800 MHz

NSA	**EN-DC between NR700 and LTE800** could be **difficult** to implement and has **impact** on the 5G rollout in NSA for rural LTE800 nodes/clusters without other FDD mid band
SA	**SA will therefore make easy NR700 rollout in specific nodes/clusters with LTE800.** But, in the same way, NR CA between NR700 and NR 800 is challenging

Cobertura 5G Vs experiencia de Cliente

Combinaciones de bandas FDD y soporte de UE

- 3GPP specifies band combinations for EN-DC and CA. New band combinations have been added for supporting the needs of the different operators and interests
  - **RAN** usually can support all band combinations from a RF point of view. Some limitations could come from SW point of view in first SW Releases but can be solved easily
  - From **UE point of view**, some band combinations are more challenging due to RF complexity in the device. Typically, support of two similar bands is complex (mid+mid combinations, low+low combinations)

State of the art in UE ecosystem

DEVICE TECHRADAR 2020H1

- **Mid + Mid** Combinations (**DC_3A_n1A**, **DC_1A_n3A**), not widely supported in 2020. More support expected in 2021.
- **Low + Low** Combinations (**DC_20A_n28**, **DC_8A_n28**, **DC_8A_n20A**) supported by few vendors. Some OEMs do not have clear plans to support them in 2021.
  - Specifically for band combinations 20A (**800 MHz**) and 28 (**700 MHz**):
    - No support from Apple, HMD, LG, Motorola, Samsung, Sony, Xiami and ZTE. Huawei is supporting this

Combinaciones de bandas FDD y soporte de UE

Impact on network strategy

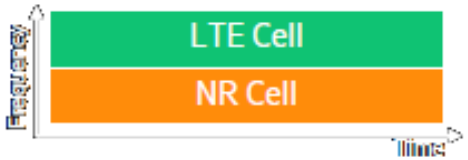
NSA

EN-DC between NR700 and LTE800 could be **difficult** to implement due to lack of support in UE ecosystem, and has **impact** on the 5G rollout strategy **for those rural areas/clusters/nodes where just LTE800 is currently in place**

SA

SA will therefore make easy NR700 rollout in specific areas/clusters/nodes with LTE800 (given that SA eliminates the dependency on LTE network**)**. But due to same reasons exposed before, NR CA between NR700 and NR 800 is challenging

Spectrum Sharing Options



	STATIC SPECTRUM SHARING	SEMI STATIC SPECTRUM SHARING	DYNAMIC SPECTRUM SHARING	ENHANCED DYNAMIC SPECTRUM SHARING
MECHANISM	• **Static frequency split between NR and LTE**	• **Subframe split** • NR DL Signals and Data Transmission in LTE MBSFN subframes. MBSFN DL resources assigned quasi dynamically to LTE or to NR • NR rate realistically <40%	• **NR DL Data Transmission in LTE normal subframes with CRS Rate** • Rate-matching for LTE CRS/SSS/PSS/PBCH • Puncturing for NR SSB, TRS, CSI-RS, SIB	• **NR DL Data Transmission in LTE normal subframes with CRS Rate** • Rate-matching for LTE CRS/SSS/PSS/PBCH • Few MBSFN subframes for NR SSB, TRS, CSI-RS, SIB, and TM9 LTE devices (depend on vendor implementation)
PERIODICITY	• -	• slow pace compatible with LTE SIB update (every 5 to 30 minutes)	• 100 ms -1 ms (depend on vendor implementation)	• 10 ms-1ms (depend on vendor implementation)
VENDOR STRATEGY	NOKIA HUAWEI ERICSSON	NOKIA	• First implementation based on this first approach but move to enhanced DSS very quickly	NOKIA HUAWEI ERICSSON

LTE ADVANCED

LTE in its definition as of 3GPP Release 8 does not meet all IMT- Advanced requirements as set by ITU to be designated a true 4G mobile communications technology.

3GPP, and the standardization body behind LTE, is addressing and exceeding these requirements while standardizing LTE-Advanced as part of its Release 10 for all relevant technical specifications.

Table 1 IMT-Advanced requirements

	IMT-Advanced	LTE 3GPP Rel. 8	LTE-Advanced 3GPP Rel. 10
Transmission bandwidth	≤ 40 MHz/≤ 100 MHz	≤ 20 MHz	≤ 100 MHz
Peak data rate (DL/UL)	1000 Mbps (low mobility), 100 Mbps (high mobility)	300 Mbps/75 Mbps	1000 Mbps/500 Mbps
Peak spectral efficiency (in bps/Hz)			
DL (4x4/8x8)	15/–	15/–	16/30
UL (2x2/4x4)	6.75	3.75	8.4/16.8 (FDD), 8.1/16.1 (TDD)
Latency			
User plane	< 10 ms	< 6 ms	< 6 ms
Control plane	< 100 ms	50 ms	50 ms

LTE ADVANCED

DESAFÍOS

Eficiencia espectral

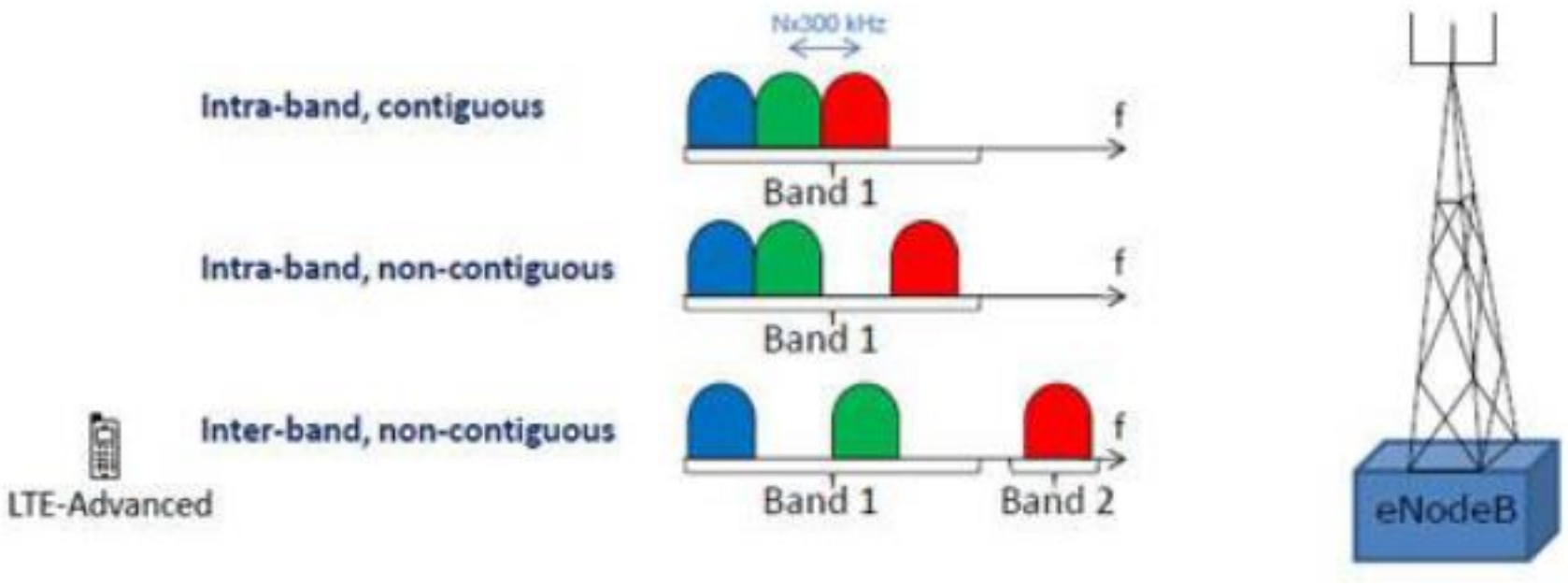
Velocidad pico

RECURSOS

Múltiples antenas

Carrier Aggregation

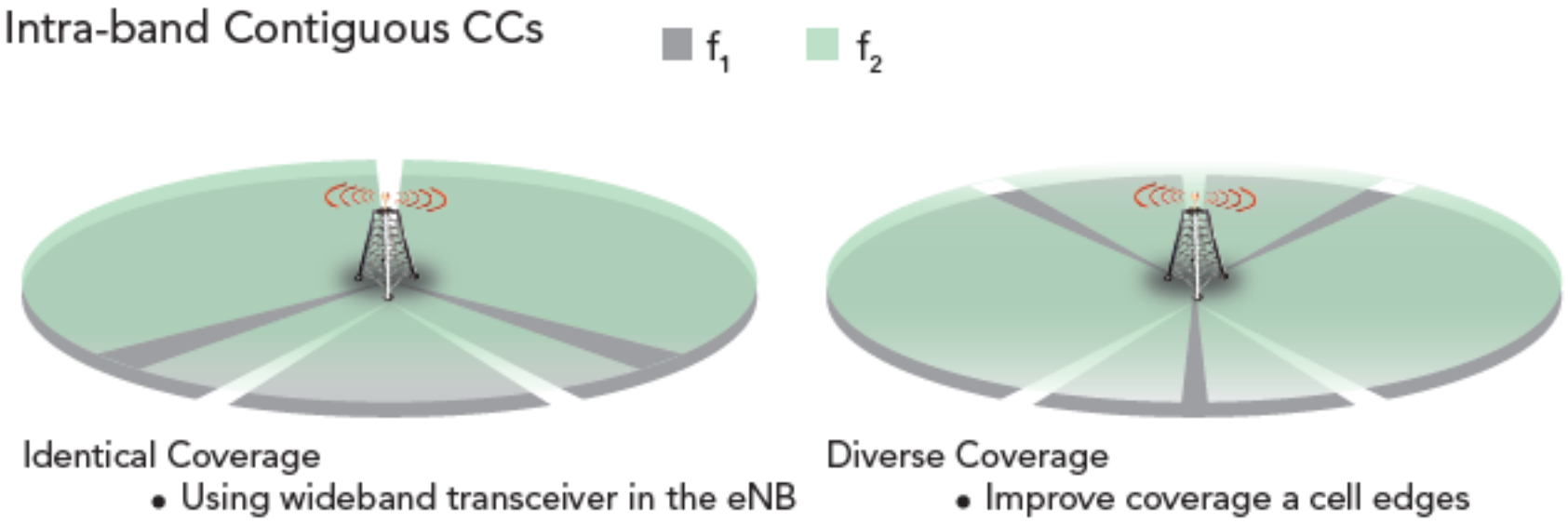
TIPOS DE C.A



Release 10 cubre Intraband contiguous e Inter-band

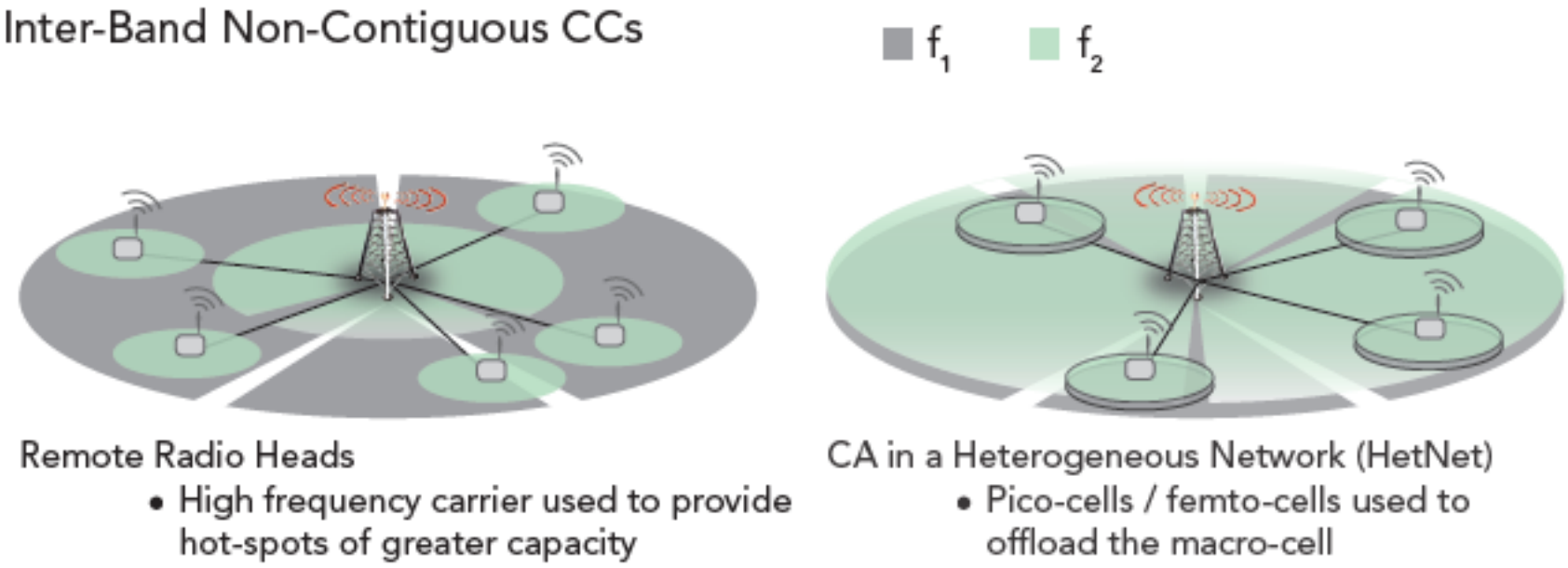
LTE ADVANCED

- One of the probable scenarios is that F1 and F2 cells are co-located and overlaid, providing nearly an identical coverage. Both layers provide sufficient coverage, and mobility can be supported on both layers. Likely scenario is when F1 and F2 are on same band having a similar pathloss profile.
- Another scenario would be a diverse coverage where F1 and F2 are co-located: F2 antennas are directed to the cell boundaries of F1, or in F1 holes, so that the coverage is improved and/or the cell edge throughput is increased.



LTE ADVANCED
TIPOS: Interband not contiguous

The usage of non-continuous bands changes the scenario possibilities for operators due to the different band propagation profile and hardware constrains.
A Remote Radio Heads (RRH) scenario can be considered when F1 (lower frequency) provides macro coverage and RRHs on F2 (higher frequency) are used to improve throughput at hot spots. The mobility is performed based on F1 coverage. Likely scenario is when F1 and F2 are of different bands.
In HetNet scenario, it can be expected to see numerous small cells and relays working on various frequency bands.



LTE ADVANCED

TIPOS: Interband not contiguous

The introduction of CA renders the previous conceptions of “frequency band” and “bandwidth” ambiguous. Indeed, LTE systems can operate on variable bandwidth for a given band ranging from 1.4 MHz to 20 MHz. Therefore 3GPP has introduced terminology and notation which serve to more clearly express the radio interface configuration. The UE’s are defined by a CA Bandwidth Class.

For intra-band contiguous carrier aggregation, UE’s CA Bandwidth Class is defined according to their number of CCs supported and their Aggregated Transmission Bandwidth corresponding to Number of aggregated Resource Block (NRB, agg). .

UE Bandwidth Class (TS36.101 r11)

Bandwidth Class	Aggregaed Transmission Bandwidth Configuration	Maximum number of CC	Aggregated Bandwidth Equivalent
A	$N_{RB,agg} \leq 100$	1	Up to 20 MHz
B	$N_{RB,agg} \leq 100$	2	Up to 20 MHz
C	$100 < N_{RB,agg} \leq 200$	2	20 MHz to 40 MHz
D	$200 < N_{RB,agg} \leq [300]$	For Further Study	
E	$[300] < N_{RB,agg} \leq [400]$		
F	$[400] < N_{RB,agg} \leq [500]$		

LTE ADVANCED

SPEED

-LTE up to 1 GBps Up / 500 MBps Down
-Bandwith of 100 MHz required
-Carrier aggregation of multiple Components Carrier (CC)
-LTE release 8 up to 20 MHz --- > Agg of up to 5 CC

FRAGMENTED SPECTRUM

-Efficient use of fragmented spectrum, irrespective of the peak data rate.
-Designed to support aggregation of a variety of different arrangements of CCs
-Includes CCs of the same or different bandwidths
-Adjacent or non-adjacent CCs in the same frequency band, and CCs in different frequency bands.
-Each CC can take any of the transmission bandwidths supported by LTE Release 8,

RB	6	15	25	50	75	100
BW	1.4	3	5	10	15	20

For FDD operation, the number of aggregated carriers in uplink and downlink may be different (although Release 10 focuses on the case where the number of downlink CCs is not less than the number of uplink CCs)

LTE ADVANCED

HETEROGENEOUS NETWORKS

-Heterogeneous network deployment typically consists of a layer of high-power macrocells and a layer of low-power small cells (e.g. picocells, Closed Subscriber Group (CSG) femtocells or relay nodes) with at least one carrier being used by both layers.

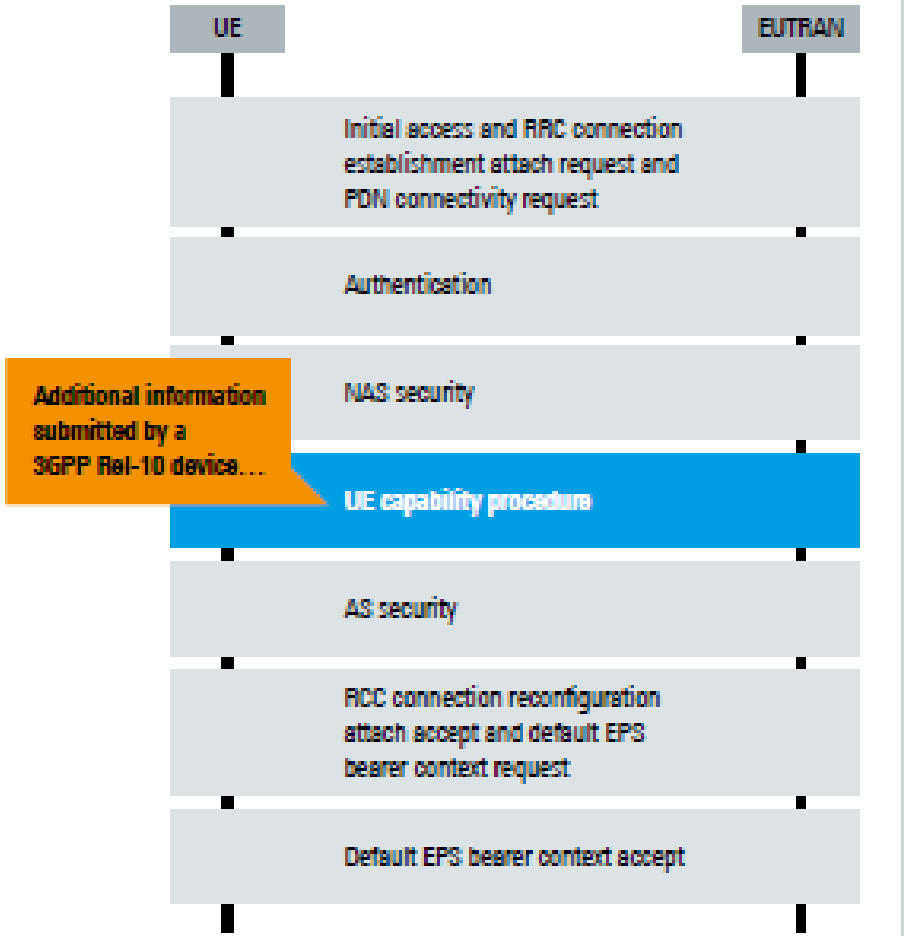
Problem: Transmissions from one cell can interfere strongly with the control channels of another, thus impeding scheduling and signalling.
Using separate carriers for the two layers, would result in inefficient spectrum.
Carrier aggregation enables multiple carriers to be used for a given layer, while interference can be avoided by means of *cross-carrier scheduling*. Cross-carrier scheduling allows the Physical Downlink Control Channel (PDCCH) on the CC of one serving cell to schedule transmission resources on a CC of another serving cell.

All CCs in Release 10 are designed to be *backward-compatible*. It is possible to configure each CC such that it is fully accessible to Release 8 User Equipment (UEs).

Each CC appears as a separate cell with its own Cell ID.
UE connects to one *Primary Serving Cell* (known as the 'PCell'), and up to four *Secondary Serving Cells* (known as 'SCells'). The PCell is defined as the cell that is initially configured during connection establishment; it plays an essential role with respect to security, NAS mobility information,

LTE ADVANCED

Figure 3 Default EPS bearer establishment procedure



HETEROGENEOUS NETWORKS

-CA se activa desde la red.
-El dispositivo debe ejecutar los procedimientos genéricos de acceso
El UE ejecuta sobre la PCCcell, “search and selection”, “system information acquisition and initial random access”.
Las SCCells son vistas como recursos adicionales
-El link con PCC se hace en base al SIB2
-La PCC se determina por el UE (depende mucho de la banda primaria de la OB)
-La red podia cambiar la PCC durante un H.O
-Solo la PCC en UPLINK llevará “Physical Uplink Control Channel (PUCCH)” para la transmisión de información de control
-Sin embargo al inicio lo mas común es CA para Downlink

Dar una razón por la cual C.A en UP es menos frecuente

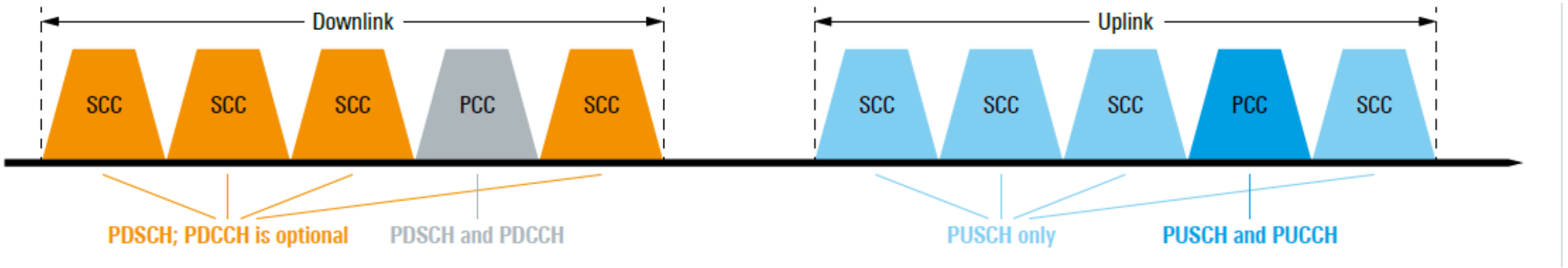
LTE ADVANCED

CA SIMÉTRICO
-Es un scenario teórico aún no explotado

PDSCH PUSCH
-….

PDCCH PUCCH
- ……..

Durante el “UE capability procedure”, el terminal debe informar a la red sus capacidades, incluyendo bandas, tecnologías de radio, y combinaciones de bandas (y tipo).
También informa “supported bandwidth classes for LTE-Advanced”. Estas clases van de la A hasta la F. Si bien las clases mas altas aún no están completamente definidas, el número de bloques de recursos va en aumento.



Carrier Aggregation y el impacto en la señalización

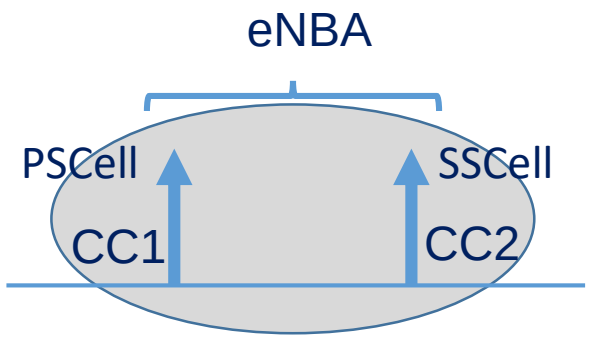
-Solo algunas capas afectadas
-El UE permanentemente conected via su PCC al Pcell. Las funcionalidades Non-Access Stratum (NAS) tales como “security key exchange and mobility information” son proporcionadas por the PCell.
Todas las “SCC” son meros recursos adicionales de transmisión.
Las capas de Packet Data Convergence Protocol (PDCP) y Radio Link Control (RLC) layer, no son afectadas (salvo tamaños de buffers lo cual depende ademas de la categoría del UE.
En release 10 comparado con rel 8 (cat 2 a 5), RLC necesita soportar tasas mayores dependiendo de la categoría de los terminales
Los terminals son configurados con SCC en la capa RRC, incluyendo la config de los parámetros de las SCC
La capa MAC) actúa como una entidad de multiplexación para los CC, y que estas son activadas o descativadas por elementos de control de la MAC.

Coming back to the extension of the previously mentioned *RRCConnectionReconfiguration* message at the RRC layer. With the help of this message extension, a maximum of four secondary cells can be activated. For each cell, its physical cell identity is sent, including the explicit downlink carrier frequency as an Absolute Radio Frequency Channel Number (ARFCN)

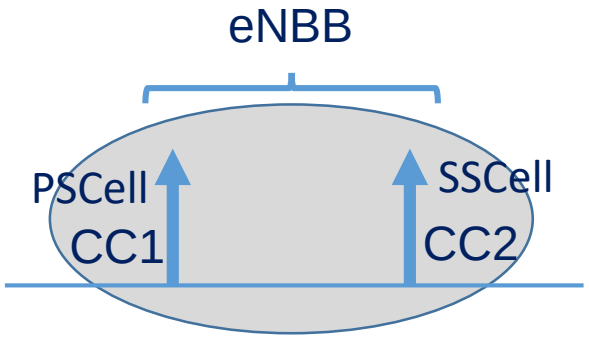
LTE ADVANCED

Carrier Aggregation

- PCC: primary Component Carrier
- SCC: Secondary Component Carrier
- PSCell: Primary Serving Cell
- SSCell: Secondary Serving Cell



Downlink and Uplink Primary&Secondary Component Carriers



Downlink and Uplink Primary&Secondary Component Carriers

A default linkage between downlink and uplink CCs is signalled in System Information Block 2 (SIB2) on each downlink CC.

A UE's Cell Radio Network Temporary identity (C-RNTI) is the same in the PCell and its configured SCells

LTE ADVANCED
Carrier Aggregation-protocolos

UE establishes a connection to a cell by following the usual Release 8 and 9 procedures.

E-UTRAN configure a UE supporting CA with one or more SCells in addition to the PCell

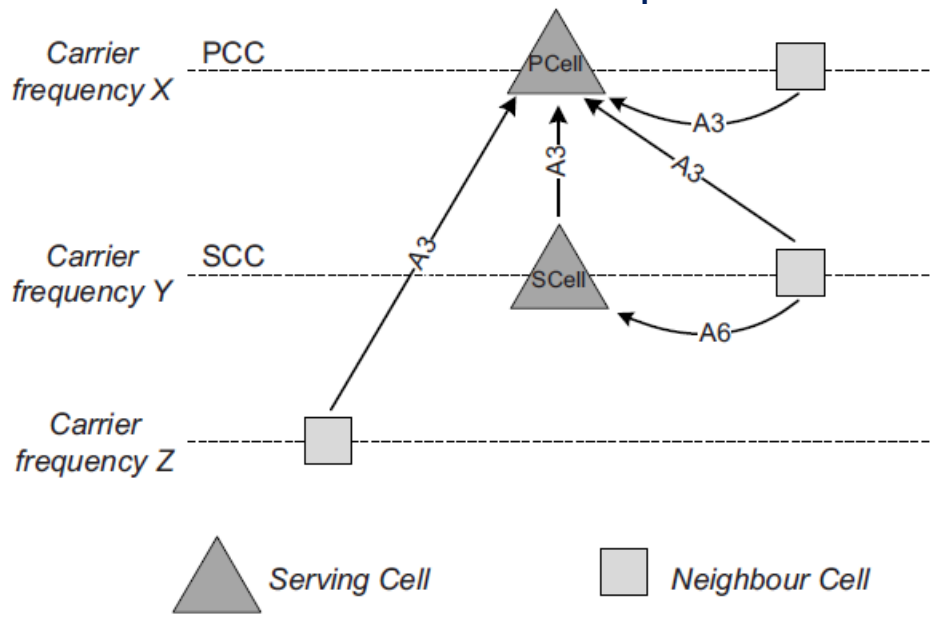
Configured set of serving cells for a UE always contains one PCell and may also contain one or more SCells.

The number of serving cells that can be configured depends on the aggregation capability of a UE.

The PCell provides the security inputs, NAS mobility information and SI for serving cells.
A single Radio Resource Control (RRC) connection is established with the PCell, which controls all the CCs configured for a UE.

After RRC connection establishment to the PCell, reconfiguration, addition and removal of SCells can be performed by RRC. When adding a new SCell, dedicated RRC signalling is used to send all the required SI for the new SCell. While in connected mode, changes of SI for an SCell are handled by release and addition of the affected SCell, and this may be done with a single RRC reconfiguration message.

LTE ADVANCED
Carrier Aggregation

MEASUREMENT AND MOBILITY

-UE sees a CC in the same way as any other carrier frequency, and a set measurement object
-Release 8 measurement events applicable for UEs configured with carrier aggregation
-There is at most one serving cell (PCell or SCell) per measurement identity
-Depending of events to be measurement A1, A2, …… is the serving cell (can be the configured serving cell (PCell or SCell) or must be the Pcell
-In addition, a new measurement event A6 is introduced for carrier aggregation
For this measurement, the neighbour cells on an SCC are compared to the SCell of that SCC